The impacts of the domestic energy transition process on the natural environment and on household welfare

by

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I declare that this thesis is my own original work. It is being submitted for the degree of Master of Arts (Economics) at the University of Stellenbosch. No part of it has previously been submitted for any degree or examination at any other university.

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Abstract

The aim of analysing the environmental and welfare impacts of the domestic energy transition process together is to enhance our understanding of their integrated nature and, thereby, inform the choices that individuals, households and society as a whole make with regard to energy use.

The literature presents different models of energy transition. In response to these, this study refines the definition and presents a new *standard model* of the domestic energy transition process, which describes how the share of different energy sources in household energy budgets change over time. It identifies a rural and an urban energy transition process and divides these into phases, each characterised by a different pattern of energy use. It also shows how the rural phases may be linked to the urban phases by urbanisation.

The literature has focused on identifying the causes of energy transition. This study reviews these causes, but goes one step further by examining the various impacts of the process. Since the ultimate aim is to seek ways of optimising the impacts of the domestic energy transition process, it is important to know what factors move the process forward and also the consequences of changing energy use patterns.

The type and amount of energy households use have implications for both the welfare and the environmental impacts of energy use. The study standardises and summarises energy use data from various studies. It is presented in terms of the *nett energy and useful energy* households derive from each energy source. Useful energy is regarded as the better indicator of welfare derived from energy use. The analysis shows an increasing trend in energy use across the entire domestic energy transition process as the energy sources households use become more affordable, versatile and convenient.

The environmental impacts of the sources of domestic energy and of energy conservation are examined separately. It is shown that in the early phases the impacts are mainly of local significance, but they become more important as the energy transition process proceeds. The impacts also tend to affect households directly in the early phases, but are more dispersed, though not less important, in the later phases.

Terreblanche's (1986) description of welfare is used for discussing the welfare impacts of domestic energy use. Two *energy poverty lines* are used to assess if household energy use levels meet their basic energy needs. The data indicates energy poverty is widespread in South Africa. The study

also shows that many aspects of energy use are relevant to the attainment of the intermediate welfare goals of growth and efficiency, stability, equity and civilisation, as well as to people's subjective sense of welfare.

Examining the environmental and welfare impacts together emphasises that to change one set will also affect the other. This needs to guide the formulation of energy policies that aim to change the domestic energy transition process. Recommendations that do exactly that are presented in the conclusion. The main emphasis is on energy conservation, since it addresses both sets of impacts in a way that minimises trade-offs.

Opsomming

Die impak van die huishoudelike energietransisie op sowel die omgewing as op welvaart word saam geanaliseer om begrip omtrent hul verweefdheid en daardeur ingligte belsuitneming van individue, huishoudings en die gemeenskap as geheel omtrent die gebruik van energie te hulp bevorder.

Die literatuur bevat verskillende modelle van energietransisie. In reaksie heirop gee dié studie 'n nuwe definisie en ontwikkel 'n nuwe *standaard model* van die huishoudelike energietransisie. Dit beskryf hoe verskillende energiebronne se bydrae tot huishoudelike energiebegrotings oor tyd verander. Die model identifiseer 'n landelike en 'n stedelike energietransisie wat in fases opgedeel word volgens kenmerkende energieverbruikspatrone. Daar word ook gewys hoe verstedeliking die landelike fases aan die stedelike fases koppel.

Tot op hede was die fokus van die literatuur op die identifisering van die oorsake van die energietransisie. Hierdie studie gee 'n oorsig van hierdie oorsake en gaan 'n stappie verder deur aandag aan die verskillende impakte van die proses te skenk. Aangesien die uiteindelike doel is om maniere te vind om die netto impakte van die huishoudelike energietransisie te optimaliseer, is dit belangrik om die onderliggende faktore en ook die gevolge van veranderings in energieverbruikspatrone te verstaan.

Die tipe en hoeveelheid energie wat huishoudings gebriuk, het implikasies vir die impak van energieverbruik op beide en welvaart en omgewing. Dié studie standaardiseer en som energieverbruiksdata van verskeie ander studies op en druk dit uit in terme van die *totale energie* en *verbruikbare energie* wat huishoudings van elke energiebron kry. Verbruikbare energie word as die beter aanwyser van welvaart uit energieverbruik beskou. Die analise toon 'n stygende tendens in energieverbriuk deur die loop van die hele huishoudelike energie-transisie-proses soos wat huishoudings se energiebronne bekostigbaarder, veelsydiger en geriefliker word.

Die impak van huishoudelike energiebronne en energiebesparing op die omgewing word afsonderlik bespreek. Daar word daarop gewys hoe die impak in die vroeër fases hoofsaaklik van plaaslike belang is, maar meer belangrik raak soos wat die energietransisie vorder. Die impak op huishoudings is ook in die vroeër fases meer direk, maar in die latere fases is dit meer verspreid, hoewel nie minder belangrik nie.

Terreblanche (1986) se omskrywing van welvaart word vir die bespreking van die welvaartsimpak van huishoudelike energieverbruik gebruik. Twee *energie-armoede maatstawe* word gebruik om te meet of huishoudelike energieverbruiksvlakke genoegsaam is om basiese energiebehoeftes te bevredig. Die data toon dat energie-armoede in Suid-Afrika wyd verspreid is. Die studie toon ook

hoe energieverbruik die beruiking van die intermediere welvaartsdoelwitte van groei en doeltreffendheid, stabiliteit, gelykberegtiging en beskawing, sowel as mense se subjektiewe welvaartservaring, beinvloed.

Deur die impak op die omgewing en op welvaart saam te analiseer, word beklemtoon dat verandering in die een ook die ander sal affekteer. Hierdie verweefdheid moet die uitgangspunt wees by die formulering van energiebeleid wat daarop gemik is om die huishoudelike energietransisie te verander. Voorstelle in heirdie verband word in die slot gemaak. Die klem is veral op energiebesparing, aangesien dit beide stelle impakte aanspreek op maniere wat afruilings beperk.

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CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER 1

ENERGY USE, HOUSEHOLD WELFARE AND THE ENVIRONMENT

1.1 Introduction

South Africa is a middle-income developing country and as such is experiencing most of the typical development problems associated with ongoing industrialisation. The most important is that it has a growing population that is urbanising and modernising rapidly. This means, amongst other things, that the domestic demand for energy and patterns of domestic energy use are in a state of flux. Pre-industrial or so called 'traditional' patterns of energy use that rely mainly on renewable resources such as fuelwood have been under pressure for a long time now. In few areas are households that use these energy sources able to meet their energy requirements from them alone. Consequently, many households rely on paraffin, coal and gas - particularly in peri-urban areas. The present electrification drive also means that increasing numbers of households are gaining access to electricity. These changes in household energy consumption patterns affect mostly black and coloured households, since white and Indian households made the transition to electricity sometime ago.

These changes in domestic energy use patterns have profound effects on household welfare. The difference between relying on fuelwood and having access to electricity is enormous. As Gandar (1991:95) has observed:

> On a typical morning in South Africa, nearly half a million people, mostly rural women, set out on the routine but arduous job of collecting firewood. ... Many will have started in the half-light of predawn, for the task might take up to nine or ten hours and involve walking a total of 20 kilometres to bring home a headload of firewood weighing about 40 kilograms.
>
> They will have been walking for quite some time when the kettles begin boiling and the toasters start popping in suburban homes. *Their* occupants begin their day with the convenience of hot water on tap, of hairdryers and electric shavers.

In addition, different forms of energy production and use have differing effects on the natural environment. Fuelwood is a potentially renewable resource, whereas paraffin, coal and gas are not. Coal fired power stations pollute the environment around them but enable households to have access to clean energy, whereas households using fuelwood, paraffin and coal suffer from local pollution effects. Then there are the environmental consequences of deforestation, destruction of nutrients, mining coal, disposing of nuclear waste, erecting electric power lines, etc. that increase or decrease in importance according to households' patterns of energy consumption.

The purpose of the present study is to describe the changing patterns of domestic energy use and to analyse the impacts these changes have on the natural environment and on household welfare and, thereby, enhance our understanding of the integrated nature of the relationship between household welfare and the environment.

The framework within which these different environmental and welfare impacts are analysed is the so called domestic energy transition process. Simply put, this process is a description or model of how household patterns of energy use change. Chapter 2 defines and discusses this energy transition and looks at the modernisation approach to analysing this process of social change. Attention is also given to different ways of conceptualising and representing this process, culminating in the presentation of the "standard model" of the domestic energy transition process which serves as the base or framework for much of the rest of the study.

Chapter 3 examines factors that have been identified or are widely regarded as causes of the domestic energy transition process. It is important to be aware of these factors when analysing the consequences of energy transition because often, if one were to look at the consequences alone, certain changes in household energy use patterns would seem to be irrational. For instance, the shift from using fuelwood to using dung and crop wastes can only be explained by the increasing scarcity of fuelwood and the unaffordability of alternatives such as paraffin, since the shift does not bring about either improvements in household welfare or less damaging environmental impacts.

Chapter 4 identifies trends in energy sources' contribution to household welfare at different stages in the domestic energy transition process. To do this, data on energy consumption levels are collated, standardised and summarised so as to determine how different energy use patterns affect household welfare. The chapter also gives attention to the availability and versatility of different energy sources.

The environmental effects of the domestic energy transition process are the focus of chapter 5. Specific attention is given to the effects different patterns of energy production and consumption for domestic purposes have on the environment and the impacts these environmental effects have in turn on individual and household welfare. Attention is also given to the scope of energy conservation measures to reduce the impacts of energy use on the environment.

The welfare impacts of energy use and the domestic energy transition process are analysed and discussed in chapter 6. Attention is given to households' levels of nett and useful energy consumption, the existence of energy poverty, the use of energy to meet basic needs and other wants, and households' subjective assessments of the contribution energy use makes to their sense of welfare.

Finally, chapter 7 discusses ways of changing the domestic energy transition process so as to minimise the negative and enhance the positive impacts of energy use on the environment and on household welfare. Ways of conserving energy within the domestic sector are also looked at. A range of recommendations are made aimed at changing energy policy and households energy consumption patterns. The chapter ends with a visual summary of the main points of the preceding chapters.

Before proceeding, it is necessary to say a word or two about the structure of the different chapters and of the study as a whole. Firstly, as noted above, the 'standard model' of the domestic energy transition process described in section 2.3.3 is used mainly as a framework for summarising the information in the final section of each of the succeeding chapters. The order in which the energy sources are discussed in each chapter is also based on this model, namely: fuelwood, dung/crop wastes, paraffin, coal, gas, and electricity. Secondly, the structure of chapter 6 deserves special mention in that it is based on the description of welfare given by Terreblanche (1986:58), who notes that once basic needs have been met there are four "intermediate" goals of social welfare, namely the attainment of growth and efficiency, stability, distribution or equity, and civilisation. The chapter therefore starts with a discussion of the use of energy to meet people's basic needs, goes on to how energy use affects the attainment of each of these intermediate goals and ends with how people's subjective assessment of the energy use patterns affects their sense of welfare. There is thus a progression in the discussion from *needs* to *wants* to *perceptions*. Thirdly, the scope of the information covered in chapters 5 and 6 is very broad. This makes it necessary to concentrate on giving an overview of the different impacts of energy use rather than an in depth analysis of each. One of the aims of the study is to draw as many aspects of domestic energy use together as possible so as to create a broad appreciation of the issues, but it does mean that it is often difficult to show how different environmental and welfare impacts of energy use are linked or integrated into a systemic whole such as described in section 1.3.1.

The rest of this introductory chapter deals with two issues that need to be addressed at the outset. Section 1.2 discusses the concept of welfare and its measurement, while section 1.3 discusses how the environment and more particularly the environmental effects of energy use are linked to household welfare.

1.2 Describing and measuring welfare

'Welfare' is a fundamental concept in economics, yet a myriad attempts to define it have failed to produce a widely accepted definition. Even more elusive has been a satisfactory standard measure of welfare. For this reason it is necessary to discuss the concept and its measurement so as to clarify what is meant by welfare in this study and to indicate how it is going to be measured or assessed. This is done in sections 1.2.1 and 1.2.2 respectively.

1.2.1 What is welfare?

Welfare is usually defined in terms of equally abstract concepts such as quality of life, life satisfaction or fulfilment, happiness, attainment of bliss, need satisfaction or social well-being. These concepts certainly suggest the richness of the idea, but, as virtual synonyms, they do not provide much guidance on "what is welfare?".

The welfare concept is founded on the assumption that people (as economic agents) have preferences which enable them to arrange any set of goods, social states or outcomes to actions in a complete order from the "most preferred" to the "least preferred". Assuming, further, that people's behaviour is "optimising" means that they will choose the most preferred good, social state or action if possible and hence move to a position of higher welfare. Thus the ability to express preferences and make choices in accordance with those preferences enables a person to become "better off" or to experience an increase in welfare (Dasgupta, 1988:15).

Underlying people's preferences and optimising behaviour is another assumption: that people are activated by self-interest. Various interpretations of this proposition are possible. Self-interest can be defined in such broad terms that practically anything is covered by it. Egoism is taken to subsume all forms of altruistic and moral behaviour. Dasgupta (1988:19) argues that such a broad definition is contrary to experience: "Not only is egoism not necessarily characteristic of all areas of human behaviour, there are areas where it is generally regarded as uncharacteristic, for example love, friendship and family relationships". A more cautious treatment of self-interest is required, one that reflects the diversity of human motivations better.

If it is assumed that preferences are not based solely on self-interest, it is possible that they are not always good indicators of individual welfare. Ng (1983:7-12) notes three reasons why this might be so: firstly, people's preferences may be affected by their consideration for the welfare of others - as when parents make sacrifices for their children; secondly, preferences may differ from what is optimal due to ignorance or imperfect foresight; and, thirdly, an individual may exhibit 'irrational' preferences based on habit, custom or principle. Each of these are relevant to the discussion of energy use, since many households' chosen energy consumption patterns do not appear to optimise welfare (in the narrow sense of individual self-interest).

A person's welfare or quality of life is affected by as many choices as there are to life itself. Such an all encompassing view is accepted as an axiom, but in practice economists, quite naturally, tended to focus on those variables that were 'economic' in nature, for instance measures of GDP/capita and income/capita. This fostered an unbalanced materialistic view of welfare which in turn affected the kinds of policies that were proposed. Fortunately perceptions are changing and more and more 'non-economic' variables are being taken into account in addition to these economic variables. A well known example of where the welfare concept has been evolving in this way is within development economics: from a narrow focus on economic growth it broadened to incorporate employment creation, then the alleviation of inequality, more recently the satisfaction of basic needs and most recently the active participation of people in development processes that are sustainable (Streeten, 1979:28 and World Bank, 1992:34).

This study accepts the integrated approach with its multifaceted view of welfare. In this view, not only do all variables affect welfare, but they may also affect each other. Economic variables, therefore, affect non-economic variables and vice versa, while at the same time detracting from or enhancing welfare - as the case may be. Unless there is a clear line of causation, it may be necessary to make some judgements about the nature and direction of these various impacts.

Welfare not only has many dimensions, but also operates at different levels. Two, the individual and social levels, are usually referred to by economists. This study focuses on a third: the household level. A household may be described as consisting of one person or a small group of people who share resources for the purpose of pursuing their mutual welfare. As a socio-economic unit, the household "is a small constituent part of the larger society" that often acts as a coherent entity (Bryant, 1990:1-5). Yet, welfare at the household level is not derived solely from such "entity actions". Because households consist of individuals and exist within society, household welfare is also partly determined by the level of welfare enjoyed by their respective members and partly by the level of social welfare. In neo-classical economics it is customary to represent household welfare with a single welfare function. Such a generalisation does not capture the multifaceted nature of household welfare and it tends to hide the widely divergent levels of individual welfare that may exist within households as a result of unequal power relationships between members (Berk, 1987:676). Therefore, indicators of both individual and social welfare should be used in conjunction with those measuring aspects of household welfare. The rest of this section examines ways in which variables of energy use are related to household welfare.

Household welfare may be represented as being determined by the extent to which basic needs and other wants/desires are satisfied, as well as by individuals' subjective assessment of their welfare position. The basic needs encompass those things without which physical survival is not possible, namely water, food, clothing and shelter. Foley (1981:1) notes that the need for energy is not often identified as a basic need, but this does not change the fact that it is one. A household requires a certain essential minimum amount of energy to cook food, heat water and provide warmth. Should that minimum not be available, the household may be said to be in a state of 'absolute energy poverty', i.e. a state where the households' basic need for energy fails to be met. At what level of energy consumption absolute energy poverty occurs differs from place to place due to varying climate, diet, housing and health. Using the fulfilment of the basic need for energy as a yardstick for measuring household welfare has a strong moral appeal founded in the claim that "a society in which the important needs of all its members are satisfied should be regarded as ranking above one in which they are not" (Dasgupta, 1988:53). The use of energy to satisfy the basic needs of cooking, heating water and providing warmth is discussed in section 6.1.2.

The other wants/desires whose satisfaction is relevant to household welfare are non-essential in so far as life will not cease without them; nevertheless they can contribute significantly to people's quality of life. Terreblanche (1986:54) argues that the satisfaction of these other needs/desires may be depicted as "intermediate goals" in the quest for social welfare. Table 1.1 lists the four goals he identifies and the guiding principles that should regulate their attainment. The third column gives the variables of household energy use that are most relevant to the attainment of each goal.

Table 1.1: The intermediate goals, principles and energy variables for the attainment of social welfare

Intermediate goals (guiding principles)	Energy related factors that affect each goal
the growth and efficiency goal (economic and distributive efficiency)	- percentage income spent on energy - price/cost of energy sources - appliance prices - efficiency of consumption
the stability goal (security and continuity)	- reliability of energy supply - stability of energy and appliance prices - provision of physical security
the distribution or equity goal (fairness and justice)	- effect of policies on access to energy sources - lack of credit to purchase appliances - incidence of energy subsidies
the civilisation goal (raising/maintenance of moral and cultural values)	- possession of appliances - lighting - entertainment opportunities - modernisation

Source: The intermediate goals are identified by Terreblanche 1986:58

Each goal represents a separate dimension of welfare, which if attained without compromising any of the other goals would enhance total welfare. Unfortunately, this is not often possible since, as noted previously, the variables of welfare are interdependent. This is especially so in the case of household energy use. So while the variables in the second column are listed next to particular goals, this does not by any means exclude the existence of overlaps and trade-offs with respect to other variables and goals. The energy related factors that affect each of the different goals is discussed in section 6.2.

Lastly, people's subjective assessment of their welfare position can be crucial to the quality of life they enjoy. Here the focus is on how people regard the contribution that domestic energy use makes to their welfare. Obviously, people's subjective assessment will be affected by the extent to which their basic needs and other needs/desires for energy have been met. Nevertheless, it is hypothetically possible for people to exist in an ideal world where all the most modern energy sources and appliances are available in unlimited quantities, and yet for them still to be unhappy or dissatisfied (Møller *et al.*, 1987:14). Variables that measure people's attitudes towards different fuels, their satisfaction with the fuels and appliances they use, the status value they attach to different fuels and appliances, and the ranking they give to the issue of energy among other issues such as education, housing, etc., are all possible indicators of people's subjective assessment of the welfare they derive from energy use. These subjective variables of welfare are examined further in section 6.3.

1.2.2 Measuring welfare

In many respects it is easier to describe welfare than measure it. An acceptable standard measure has eluded economists and other social scientists thus far. This is hardly surprising in view of the richness and encompassing nature of the concept, as well as the subjective and very personal experience of it. Indeed, it is through trying to devise measures of welfare and through assessing their adequacy that a clear understanding of the multifaceted nature of welfare itself has evolved. In this section, however, no attempt is made to expound the merits/limitations of or conditions for measuring welfare in terms of utility, consumer surplus, or the money-metric. Instead, the rest of this section gives attention to the range of welfare indicators commonly used in development and quality of life studies and to the indicators used in the rest of this study.

The following ways of measuring or assessing welfare are used in development and quality of life studies:

(i) *Economic indicators:* These are measures of economic characteristics like GDP per capita, household income, per capita income, expenditure and consumption. They are widely used as indicators of welfare, but since the early 1970's there has been a growing appreciation of their limitations. This is reflected in the *World Development Report: 1990* (World Bank, 1990:26) which notes that while "household incomes and expenditures per capita are adequate yardsticks for the standard of living" neither measure "captures such dimensions of welfare as health (and) life expectancy ...".

(ii) *Social indicators:* These are measures of physical and social characteristics or conditions such as nutrition, life expectancy, under 5 mortality, housing, access to drinking water, literacy, etc. These indicators were introduced to complement the conventional economic indicators and thus create a more balanced picture of welfare. Since the mid-1970's their use has become widespread, largely due to the emphasis on the provision of basic needs in development strategies. It has also been realised that there is little to distinguish social indicators from economic indicators in view of the fact that "social indicators can assume economic significance, whilst economic variable may also be indicative of social conditions" (Møller *et al.*, 1987:5). Hence, they are often referred to as socio-economic indicators. In all cases these indicators give a direct measure of some aspect of existence; they are therefore objective measures, but how they relate to welfare still needs to be judged in relation to some (subjective) norm. Usually it is fairly obvious - richer, healthier, more educated people are assumed to be happier than ones less so. However, is it indeed so obvious - does material privilege always imply a higher level of welfare? Many social scientists have taken the view that the experience of welfare is a more complex phenomenon dependent on a wide range of social, physiological and spiritual factors in addition to material circumstances.

(iii) *Subjective social indicators:* These are measures of people's perceptions of their life experiences, circumstances, frustrations, satisfactions and aspirations. They may be studied qualitatively or quantitatively. The former method gives great insight into a particular person's circumstances, but is not amenable to comparisons. The latter method measures subjective feelings and reactions to their quality of life either by rudimentary scaling of reactions or by the classification of choices between alternatives (Møller *et al.*, 1987:7-8). Such indicators may measure very specific aspects of people's lives which are relevant to welfare (personal relationships, status or work satisfaction) or more general experiences of life (participation in decision-making or freedom of choice).

(iv) *Public mood opinion polling:* These are similar to the subjective indicators just mentioned, except that the issues chosen for measurement are extremely general: how satisfied are people with life at present/with the economic situation/with the public service, etc. (Møller *et al.*, 1987:10).

The above range of indicators reflects the multifaceted nature of welfare, though they are seldom (if ever) all used in a single study. The data requirements would be vast and data would be impractical to collect and interpret. Consequently, social scientists usually only attempt to study a particular aspect of welfare, such as income or nutrition. To a certain extent then, 'what' is being studied tends to determine 'how' its impact on welfare is measured. This is also true of the relationship between domestic energy consumption and household welfare.

One of the aims of this study is to emphasise the diverse nature of the relationship between energy use and household welfare. Therefore indicators of many different aspects of energy use are used, since each emphasises a different dimension of how domestic energy consumption affects welfare. The choice of indicators is largely determined by what is discussed at particular points in the study and by what has been reported in the literature. Minimal original data collection or measurement was undertaken, since, as noted earlier, the purpose of this study is to draw information from existing studies together to create an overall view of what has been learnt so far.

In some cases the format in which the information was presented in some sources has been altered or manipulated in order to facilitate comparison with data from other sources. These changes are described where relevant. Nevertheless, a few points in this regard warrant discussion now. Firstly, the economic indicators generally only take data on commercialised energy sources into consideration. This may not be a problem if the households being studied are completely reliant on such energy sources, but this is rarely the case in a developing country. Indeed, in many areas non-commercial energy sources are so important that to exclude them would lead to erroneous conclusions. It is possible to postulate various shadow pricing procedures that could be used to 'monetise' these energy sources. However, the results of such procedures would tend to be sensitive to the assumptions on which they are based. No energy studies that use shadow pricing could be found. The reason for this may be that it is easier and more certain to measure and compare the physical quantities of energy derived from different energy sources. The economic indicators are, nevertheless, useful measures of the impact energy use has on those dimensions of household welfare that are linked to income, expenditure and relative prices. In addition, other indicators are used to measure the cost of non-commercial fuels, e.g. the time spent collecting them or the distance walked to fetch them.

Secondly, data on the physical amounts of energy sources consumed by households or per capita are only comparable if the units of measure are measuring the same thing. So kilograms of fuelwood and coal are not comparable unless manipulated into a common measure such as coal equivalents, oil equivalents, kilowatt hours or calorific values (see Foley, 1981:312-313). Most South African studies use calorific content or energy output of the different energy sources to generate data on nett energy consumption (see table 4.1). Such data are comparable, but still do not necessarily give an accurate indication of the relative contribution each energy source makes to welfare. For this purpose the relative amounts of *useful* energy derived from each energy source are calculated using data on the energy-use efficiency of each (see table 4.2). Useful energy consumption is used as the main unit of comparison in this study.

The third point concerns the specification of an energy poverty line. Any poverty line, whether measuring income, consumption, nutrition or energy use, may be thought of as comprising two elements: an amount of whatever is being measured that is essential to sustain life, and a further amount that may be regarded necessary to participate in the everyday life of society. The first amount is objectively determinable, being based on the physiological needs of people, both at particular points in time and averaged over longer periods. The second amount is far more subjective. It will vary from community to community depending on what each one regards to be an acceptable minimum level of consumption (World Bank, 1990:26-27). Few studies have considered what represents an adequate level of domestic energy consumption. Cecelski *et al.* (1979:32-33) refer to some that suggest 9-12 GJ (gigajoules) per year as the amount needed for the "minimum provision of food and shelter", and others that estimate 43 GJ per year to be the "minimum requirement for a satisfactory life". They note that the former probably underestimates needs for those areas that require some space heating. These estimates are not very useful in this context, since it was not possible to find the original studies from which they were taken. Nevertheless, data on nett energy consumption per capita in most of the studies referred to here are of the same order of magnitude as the lower of the above estimates, i.e. 9-12 GJ. The types of fuels used and patterns of energy use reported in many of these studies suggest that these levels of energy use are low. Therefore, in the absence of further information the energy poverty line for domestic nett energy consumption is assumed to be 10 GJ per capita per year. By similar reasoning, it is assumed that the energy poverty line for useful domestic energy consumption is 1.5 GJ per capita per year. This suggests an average energy-use efficiency of about 30%, which does not appear unreasonable in the light of the information given in table 4.2. It is important to note that households with energy consumption levels close to these poverty lines would, under normal circumstances, be consuming more energy than is 'essential to sustain life', but they would nevertheless be consuming less than what society generally considers sufficient. Indeed, the amount of energy essential to sustain life is almost totally time dependent and should not be described as an average value over a year, e.g. if households require energy to keep warm on a winter's night their need is immediate and absolute. This means that even if a households' average level of energy consumption is well above the poverty line, it is still at risk of a fatal shortfall in energy at a particular point in time. Obviously households with very low levels of energy consumption are more at risk.

Further confirmation for the choice of the above poverty lines is given by the fact that they are about 10% greater than the average levels of energy consumption calculated for households in the rural areas of what was formerly Bophuthatswana. Eberhard and Dickson (1991:34-35 and 90) describe these household energy consumption levels as "unsatisfactory". Further study of what constitutes an adequate level of energy consumption under a variety of South African conditions is definitely needed.

Fourthly, although this study focuses on household welfare, much of the data are presented in per capita terms. The reason for this is that per capita data eliminates distortions caused by differences in household size which may vary by a factor of three between communities. Household data are used where useful. It should also be remembered that the marginal increase in energy consumption tends to decline as household size increases, since the energy demand for uses such as space heating, cooking, lighting and entertainment is only weakly correlated to the number of people in the household, i.e. there are domestic energy economies of scale..

Fifthly, and lastly, it should be noted that the measurement of and reporting on objective and subjective indicators are skewed towards the former. The reason for this is that data on objective indicators are more easily come by. The view that these indicators are 'more scientific' than subjective ones also probably plays a role. Such a view is based on a narrow materialistic interpretation of welfare and must therefore be rejected as erroneous. The subjective, non-material dimensions of welfare are as important and it is to be hoped that this will be recognised in future energy studies. In the meantime this study can only reflect the imbalance and point to areas where appropriate subjective indicators are needed.

1.3 Environmental conservation and community development

The aim of this section is to examine the integrated nature of the relationship between the environment and household welfare. Section 1.3.1 elaborates on aspects of the 'integrated approach'; section 1.3.2 discusses the links that exist between the environment and households; and section 1.3.3 argues that it is difficult to say which links are important, but notes that there are three levels at which domestic energy use is linked to the environment.

1.3.1 The integrated approach

The integrated approach is based on the view that the environment and household welfare are inseparable or they are interdependent. This view is based on the axiom that people's existence and quality of life are inextricably integrated with the existence and quality of the natural environment.

Obvious as this may be, the tendency in the past was to treat community development and environmental conservation separately. Either the one or the other served as a focus around which research was conducted, conclusions drawn and policy recommendations made. This fragmented approach gave rise to the impression that the objectives of development and conservation were diametrically opposed to each other. In a nutshell the impression was: development exploited the environment; conservation limited the opportunities for development. Examples that appear to confirm these statements are common: the destruction of rain forests to provide ranching land or rice paddies, the disruption of river ecosystems by the construction of dams, expenditures on pollution measures limiting a company's capacity to expand, and the removal of communities from land set aside for conservation - to mention just a few.

Despite appearances, the idea that development and conservation conflict is only superficially true. The impression can be debunked by examining the underlying motives of each. Starting with development: during the past forty years the approach to development has undergone some changes; from economic growth it progressed to employment creation, then to the alleviation of inequality, more recently to the satisfaction of basic needs and most recently the active participation of people in development processes that are sustainable. Throughout these changes, however, the motive remained the same, indeed each successive approach has been more finely tuned to the motive, namely: "to give everyone the opportunity to live a full life" (Streeten, 1979:28-31). The approach to conservation has undergone similar changes, but again the motive has remained constant: to conserve the natural environment because of the material, cultural, intellectual and aesthetic benefits people derive from it (Green, 1985:8-11). While these motives may appear different, there is actually little to distinguish them from each other. They are equally anthropocentric, utilitarian and materialistic. In fact, they can be reformulated into a common motive: to maintain and improve people's quality of life. Given the broad nature of this objective, it is hardly surprising that there are different ways of trying to achieve it. It would, therefore, be more accurate to depict the apparent conflict between development and conservation as a disagreement over the approach or method to be used to enhance people's quality of life. Which is the better approach will differ with circumstances and in many instances "economy and ecology will have to merge" in the decision making process (Brundtland, 1987:*x*).

The integrated approach treats the natural and human environments as integral parts of a whole and so creates a framework for assessing developmental and environmental problems. However, simply analysing them on the same terms will not resolve all conflicts of approach or cause the trade-offs inherent in all decisions to disappear. What it will do is foster rational, innovative and balanced decision making that takes cognisance of the integrated nature of problems as well as of their short and long term implications. Policies that involve trade-offs are inevitable, but it is important that the choices that are made do not impair development and conservation prospects in the long term.

The integrated approach is well suited to dealing with the issues that characterise the field of domestic energy use. Firstly, the integrated approach provides a rational framework for dealing with the links between people and the environment. Such links are readily identifiable and significant in the field of domestic energy use. Secondly, the integrated approach has a long term orientation which is desirable in a field replete with instances where short term gains in the quality of life may be made at the risk of incurring long term losses. Thirdly, the integrated approach provides a paradigm where the objective is to enhance people's quality of life so that any information on proposed development and conservation policies is assessed on the same terms with the aim of identifying an innovative, harmonised and balanced set of policies. Such an approach is desperately needed in the energy field, where development and conservation policies often seem to be pulling in different directions instead of complementing each other.

1.3.2 Links between the environment and households

Simply to state that human and environmental welfare are integrated is not sufficient to make it so. Therefore some instances to substantiate the claim are examined here, along with a number of other relevant points.

In this study the term *environment* is restricted to the meaning it bears in popular usage: to refer to the air, water and soil, plants and animals, habitats and ecosystems; the objects that the environment "environs" are people (Hawley, 1986:11); and the relationship between the environment and people is handled within the economic frame of reference. This implies (a) that people are the measure of value both in the definition of the environment and in the evaluation of environmental changes, and (b) that the environment is treated as a kind of natural asset or non-reproducible good from which people (households) derive various economically valuable direct and indirect services. Four classes of such services exist: the provision of basic needs, the satisfaction of other needs, the disposal of wastes and amenity services (Freeman *et al.*, 1973:20). These are now elaborated upon to illustrate how households benefit from the environment and how their actions in turn affect the environment.

The first and most important class of services involves the support of human life. The environment provides a habitat for people. People depend on the environment for those things that sustain them: air, water, food, shelter, clothes and energy. To 'delink' people from the environment would be like cutting the umbilical cord that links a foetus to its mother. The result would be a cessation of human life. The second class of services is closely related to the first, but has more to do with the production of non-essential goods and services that enhance people's welfare by simplifying tasks, and by providing services and opportunities over and above those required to satisfy basic needs. The environment serves as a source of material inputs or resources for the economy. The aim of all primary activities - mining, forestry, fishing and agriculture - is to mobilise these resources for people to use either as they are or in secondary production processes. The third class of services that the environment performs is the removal, storage or assimilation of the residuals generated as by-products to human life and economic activity. Natural environmental processes such as wind, rain and gravity remove wastes to harmless areas, or disperse them into harmless concentrations. Chemical processes and biological action transform wastes into harmless and sometimes useful substances. The fourth class of services are the so called amenity services. Beautiful, peaceful and clean environmental surroundings provide opportunities for recreational activity, aesthetic enjoyment and cultural experiences, all of which contribute positively to people's welfare.

So far only the welfare enhancing effects of utilising environmental services have been referred to. This is not the complete picture; there is also a reverse side. The environment is a limited capital resource, so use of a particular service usually reduces the size and quality of the resource which impairs the quality and supply both of that same service and of the other classes of services. This is particularly relevant to the second and third classes of services mentioned above, i.e. the environment is the source of raw materials, but the extraction of non-renewable resources leads to a decline in the stock of these resources and, depending on the method of extraction, may reduce the environment's capacity to supply life support and amenity services. The utilisation of renewable sources tends to have less of an impact, but even here the method of collecting and withdrawing the material is important. Where potentially renewable resources like soil, water, fish and forests are overutilised (i.e. harvested faster than stocks can be regenerated), the future supply of these materials is jeopardised and the quality of the environment reduced.

The waste disposal services under normal circumstances maintain the quality of the environment. These services are renewable in some instances and strictly non-renewable in others. In the former instances renewable chemical and biological processes transform or break down potentially harmful wastes into harmless substances. These processes usually operate effectively up to a certain threshold level but if this is exceeded their renewable nature may be jeopardised and they may even cease to operate. In the latter instances the environment is a place where harmful wastes that do not decompose or become less harmful over time continue to exist. They are either dispersed throughout the environment at concentrations too low to be harmful or 'isolated' in 'dump sites'.

Where more wastes are dumped into the environment than can either be effectively neutralised or effectively dispersed/isolated, not only is the environment's capacity to deal with waste reduced, but also its capacity to supply other services. The life support services may be impaired by the release of toxic wastes and by wastes affecting the quality and supply of clean air and water. The supply of materials, particularly forestry, agricultural and aquatic products, may also be affected, as well as the quality of the amenity services available to people to enjoy. Other negative impacts arise because some environmental processes, especially food chains, cause certain wastes to re-accumulate into harmful concentrations, and others, such as the action of sunlight, transform seemingly innocuous wastes into harmful secondary pollutants.

How is domestic energy use linked to the environment?

People need energy, which is only available from the environment. The result is a link between the environment and households that is essential for the support of human life. On a macro scale energy stocks are in no danger of being depleted, but on a micro scale access to or the availability of energy resources is restricted by factors such as low incomes, local resource depletion and shortcomings in energy policies. As a result many households experience energy poverty. Under normal circumstances the use of energy to satisfy basic needs will only have limited detrimental effects on the environment, effects that are well within its capacity to neutralise. However, in regions - particularly densely populated resource poor ones - where the demand for energy exceeds the available supply, severe damage may be done to the environment.

In addition to using energy to meet a basic need, many households use it to meet other needs/desires. The link that this creates between households and the environment is of a different order to the one just described. In this instance the environment serves as a source of energy inputs or resources that are used to produce goods and services over and above those necessary to satisfy basic needs. The vast amount of energy being used for these purposes means that not only are energy resources being depleted, but also that the environment is being affected by the processes whereby extensive quantities of petroleum, coal, natural gas, uranium, hydro energy, etc. are extracted, conveyed and converted into useful forms of energy. Admittedly most of these impacts cannot be ascribed solely to the use of energy for household purposes, as is discussed later.

The wastes generated as by products in the production/ consumption of energy also link households to the environment. Where small amounts of fuel are consumed at dispersed points, as for example in rural households, the resulting stream of waste is easily neutralised by natural processes and the environment is left largely unaffected. However, where large amounts of fuel, especially coal or oil, are processed or burnt at a single point (a power station or a refinery) or at points close together (urban households), the resulting stream of waste may exceed the environment's capacity to store, disperse or assimilate it effectively. The impact that undispersed, unassimilated waste has on environmental quality may vary from mild to devastating depending on the type of waste, its concentration and the time for which it remains so. A decline in environmental quality impairs the supply of environmental life support services, which may in turn affect people's health, causing anything from discomfort or irritation to chronic illness, paralysis and cases of poisoning or total breakdown, even death. People's health forms a direct link between household welfare and the quality of the environment, therefore it is discussed along with the other environmental impacts of energy use in chapter 5.

The dumping of waste also impairs the environment's capacity to supply amenity services which in turn reduces household welfare. Even though this particular link can only be subjectively perceived, it exists and is important.

Lastly, ways of controlling and regulating waste streams represent yet another link between households and the environment.

As noted above, chapter 5 examines the impacts of different patterns of energy production and use on the natural environment, as well as the scope for conserving energy. Therefore most of these links are discussed in greater detail there.

1.3.3 Which links are important?

The previous section noted some of the links between household welfare and the environment. In order to simplify the discussion it would be convenient to be able to isolate and concentrate on the 'more important' links, but as the following example demonstrates, it is not always clear which links are important and which not. In the rural areas of the former Transkei fuelwood consumption is about 650 kg per person per year. It is estimated that by the year 2000 Transkei's rural population will number about 3.44 million, which means that the demand for fuelwood would be in the order of 2 236 000 tonne per year. The sustainable supply of fuelwood in the year 2000 is estimated at 875 000 tonne per year, which means that each year there will be a deficit of 1 361 000 tonne (Aron *et al.*, 1989:10 & 29). If we assume that each tree yields 125 kg of fuelwood, then each person need cut down only 5 trees per year. However, during the course of the year more than 10 000 000 more trees than the sustainable yield will then be cut down. While 5 trees may not seem to matter, 10 000 000 trees in an area as small as the Transkei do matter.

Similar examples where seemingly insignificant acts of innumerable households combine to produce major impacts on the environment are common. Does this make all domestic actions involving energy use important? And if so, which of these important actions should be addressed first in order to ameliorate households' negative impacts on the environment most effectively? In cases involving localised environmental impacts both, causal and quantitative links are usually easily determined and as a result the appropriate method of reducing the impact may be identified as well. For instance, nearly all the indoor pollution in a particular household may originate from the open hearth, so appropriate methods of reducing the pollution may involve increasing ventilation, installing a wood stove with a chimney or changing to a cleaner fuel. In cases involving environmental impacts such as global warming, desertification, or city level air pollution, it is more difficult to determine 'how much' of a particular impact is caused by energy use in the domestic sector, let alone by individual households. Consequently, it is also difficult to specify appropriate measures at the household level for reducing such impacts.

Another dimension of this problem arises where threshold levels are exceeded. Under normal circumstances low levels of pollution are tolerable in the sense that they do not impair the environment's life support service to any great extent. However, should the concentration of any pollutants exceed a particular level (the threshold level), the environment's capacity to absorb, disperse or otherwise neutralise them may be impaired and its capacity to support life may break down. Such a breakdown usually occurs very rapidly and the consequences may be disastrous. A question that might be asked is: Did domestic energy use contribute to the base amount that would represent acceptable waste discharge or to the critical amount that caused the threshold level to be exceeded? A simple answer is not possible since in most cases discharges are cumulative. Nevertheless, it could be argued that domestic uses of energy can be divided into those that are essential, in the sense that they fulfil some basic need, and those that are non-essential. The wastes arising from essential uses could then be regarded as acceptable and reasonable, contributing only to the base level of discharges, whereas the wastes from non-essential uses would always be regarded as contributing to the critical amount. This approach is already applied when direct controls are used to limit the use of private vehicles and open fires during pollution crises in large cities (Baumol and Oates, 1988:194). Despite its logic, it is still only a partial answer, since often simple measures can significantly reduce the effect even essential uses of energy have on the environment.

Instead of trying to identify the 'more important' links, it may be more meaningful to single out those links whose impact on the environment is excessive in the sense that it could easily be ameliorated or prevented without much effort or cost. So the impact that an inefficient hearth fire and an inefficient power station have on the environment would be regarded in the same light if the amount of effort and cost of ameliorating the impact is proportionally the same for each. In other words, the marginal social benefit of each Rand spent on conservation or pollution control must be equal across all activities. This study does not venture into the field of calculating marginal costs and benefits, but the principle informs the discussion in the following chapters.

Even if efforts to identify the more important links are not altogether successful, there is something to be gained from distinguishing between macro, intermediate and micro level impacts - obviously keeping in mind the point that small impacts often add up to create larger impacts. Starting at the small end; micro level impacts refer mainly to the very localised effects domestic energy use has on the environment both in or around the dwelling or area of use, and at the places where the energy resource is taken from the environment, refined and distributed. The impacts close to the dwelling are easily linked to the specific household's pattern of energy use and include indoor pollution, localised smoke pollution, a point for depositing waste (ash) and a loss of local amenity services. Other micro impacts include localised habitat destruction from mining operations, the cutting down of trees and the erection of power lines; local pollution from a mine, power station or refinery, with a loss of amenity as well; and a loss of nutrients if crop wastes and dung are used as fuels. Generally these impacts may be linked to particular activities such as mining, cutting down trees, refining oil or generating and distributing electricity. However, to link them to the energy consumption of individual households is often difficult, since their separate impacts are not readily identifiable. Nevertheless the impact of all households together is usually obvious.

The intermediate level impacts include neighbourhood, city or regional air pollution, the pollution of river systems or areas of ocean, resource depletion in a particular region, deforestation and the disruption/destruction of ecosystems. These impacts are still largely geographically confined, and so can be linked to the energy consumption patterns of households within specific areas. For instance, air pollution in Soweto cannot be blamed on the residents of KwaMashu. Sometimes, however, an environmental impact in one area may be causally linked with households outside that area. For instance, all the households, whether in Pietersburg or Cape Town, that receive electricity from Lethaba, Kendal, Duvha and Komati power stations are directly responsible for a proportion of the air pollution in the Witbank area. It should also be noted that if these power stations were more evenly distributed across the country, they would most probably only contribute to base level pollution in different localities, instead of to the critical levels which cause the pollution problems in and around Witbank.

The macro level impacts cover the larger inter-regional and global environmental problems. These include global warming, acid rain, ozone depletion, desertification, ocean pollution, toxic waste build-up and the loss of biological diversity. The individual household's contribution to these impacts is so small as to appear insignificant. Even the contribution of the entire domestic sector in South Africa is not very great. Yet it is with these impacts in mind that the example at the beginning of this section was given. An individual household's use of energy is usually linked to these problems and although its contribution may be minuscule, it is nevertheless important. The micro level impacts combine to produce intermediate impacts, and all impacts combine to form macro impacts. Indeed it is with reference to the micro origins of the macro problems that the maxim 'think globally, act locally' was coined within the environmental movement. By addressing the small impacts, the larger impacts are also ameliorated.

In the following chapters reference is made to these levels of linkage between domestic energy use and the environment, but they do not necessarily form a framework for the discussion.

CHAPTER 2

THE DOMESTIC ENERGY TRANSITION PROCESS

Study of the domestic energy transition process in South Africa has thus far focused on describing the process and on identifying and analysing which societal factors influence it. The aim of this chapter is to discuss various aspects of the domestic energy transition process in order to set the scene for the rest of the study. Section 2.1 defines and discusses the concept of energy transition; section 2.2 investigates the modernisation approach to analysing a process of social change such as the domestic energy transition process; section 2.3 describes and discusses different ways of conceptualising and representing the domestic energy transition process; and, lastly, section 2.4 presents a possible framework for comparisons.

2.1 Definition of the domestic energy transition process

Energy transition has been depicted as "the process whereby the consumption patterns of fuels used by a population change over time" (Viljoen, 1990:1).

The following points may be made concerning this definition:

(i) The change in energy consumption refers to two tendencies: first, the way one fuel replaces another over time and, second, the increase in energy consumption over time.

(ii) The term 'fuels' covers not only the conventional fuels such as fuelwood, coal, paraffin, gas and electricity, but also includes energy sources such as dung, crop residues, biogas, solar energy, wind energy, hydro-energy and geothermal energy. Even measures to increase energy efficiency are relevant. Indeed, it would be more accurate to speak of energy sources rather than of fuels.

(iii) The time period over which the energy transition takes place is long, decades rather than years. This distinguishes the transition process from short term fuel substitution that occurs with seasonal and other temporary changes.

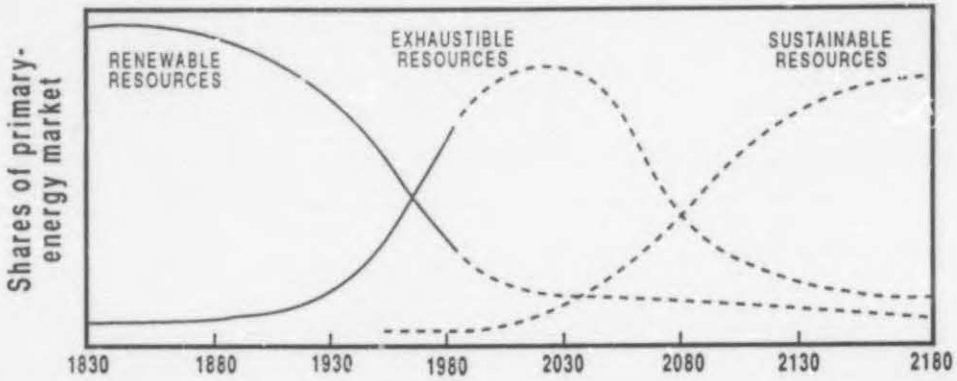
(iv) The definition does not specify the causes or the p[illegible]y transition. These may vary across societies, regions, sectors of the p[illegible] the economy and across time.

Doppegieter *et al.* (1991:45) note that the energy transition is often described in terms of a switch from:

- non-commercial to commercial forms of energy;
- traditional to non-traditional forms of energy;
- conventional to non-conventional forms of energy.

While the switch from one of the above categories of energy to another may be in line with the above definition, the classification of the different categories is not unproblematic. For instance, fuelwood is normally classified as non-commercial although much of it is sold; the definition of what is traditional or non-traditional varies with social and geographical factors, as well as over time. The same argument applies to conventional or non-conventional energy sources (Cecelski *et al.*, 1979:9). In addition, describing the energy transition process in terms of these categories places the focus on the changing characteristics of the energy source used, rather than on the actual switch from one energy source to another. It is the shifts that are important here, so the above categorisations will be used sparingly.

Sassim (1980:116-117) identifies yet another way of characterising energy transition (at the global level), which is depicted below.



Source: Sassim, 1980:116

Figure 2.1: The global energy transition

As population increased and industrialisation progressed in developed countries, local renewable energy resources such as wood were replaced by exhaustible energy resources such as coal and oil. As these resources are depleted and, one might add, as environmental concern grows, Sassim (1980:117) predicts a transition to sustainable energy resources, which he says includes breeder reactors, direct solar power and fusion power. While the switch from renewable energy resources to exhaustible energy resources and, finally, to sustainable energy resources may be in line with the above definition of energy transition, the focus is again on the changing characteristics of the energy sources used rather than on the switches from one energy source to another.

The usual progression of the transition process is assumed to be from wood to paraffin/coal, to gas and, finally, to electricity. As we shall see, this representation is too simplistic. The actual process of energy transition usually entails a gradual replacement of one energy source by another. At any one time a variety of fuels may be used simultaneously, although one will usually predominate during the different phases of the transition process.

For present purposes Viljoen's definition is too broad. It covers all energy consumed by a population irrespective of whether that energy is used in the domestic, transport, productive or service sectors. No doubt an energy transition at this macro-level can be identified (consisting of the weighted sum of the energy transitions occurring in each sector), but that is not the focus of this study. The focus here is on the energy transition in a specific sector - the domestic sector.

The following definition is certainly not the last word in this regard, but it makes provision for the points made about the previous definition and takes the narrower focus of this study into account:

The domestic energy transition is the process whereby the energy sources and the quantity of energy used by a population for domestic purposes change over the long run.

Again the following points are pertinent:

(i) The transition process is explicitly divided into two components: changes in energy sources used and changes in the quantity of energy used.

(ii) The 'domestic purposes' referred to include cooking, heating water, space warming/cooling, lighting, house cleaning and home entertainment, i.e. all energy uses that take place in the home environment, but excluding transportation and home enterprises.

(iii) The 'long run' is used to distinguish the process of energy transition from the temporary, reversible process of fuel substitution. It is used to indicate the transition is permanent, rather than slow. In some cases the transition may be rapid, as with electrification.

2.2 Modernisation theories and the domestic energy transition process

Many definitions of modernisation exist. Most incorporate the ideas that it is "a type of social change which is ... progressive in its effect" (Tipps quoted in Senekal, 1980:21). What is meant by "progressive" is seldom specified. Senekal (1980:21) suggests that it refers to a shift whereby the social system develops another level of existence that represents a real and/or perceived improvement on the previous level of existence. According to Berger and Godsell (1988:289) the new level of existence would appear to be an increasingly rational, technological mode of living. Study of the process of modernisation has lead to the development of various socio-economic theories of modernisation. No attempt is made to delve in depth into the pros and cons of these different theories, nor is attention given to the terminological debates prevalent in this field of social analysis. This section aims to show how the different theories of modernisation can assist our understanding of the domestic energy transition process.

The domestic energy transition process is widely regarded as a subcomponent of the broader processes moving societies from the traditional to the modern form. Indeed, the traditional-modern dichotomy that characterises the modernisation perspective is current in almost all discussions of domestic energy use. The aim of this section is to examine briefly how the domestic energy transition process can be treated in the light of the modernisation approach to the study of social change.

Common to all modernisation theories is the underlying belief that because of the diffusion of Western or 'modern' economic/technological/political institutions, processes, standards and norms, and because of the need for compatibility within social structures, developing societies will gradually take on the characteristics of developed ones (Blumer, 1990:22). In other words, it is assumed that traditional societies will converge to the model of modern societies (Jaffee, 1990:34).

Exactly how the diffusion takes place is uncertain. The earlier modernisation theories suggest that "pictures of the future" are the moving factors (Lerner, 1968:387). Every more developed nation transmits pictures of itself to less developed societies, which receive them and decide which of them constitute the preferred picture of its own future. Once a particular picture has been accepted it begins to influence policy planning. Efforts are made to plan the transfer of 'modern' characteristics into the less developed societies so as to replicate the picture. The model on which such change is based is thus exogenous to the society in which the change occurs.

This picture effect is similar to what is referred to in development literature as the demonstration effect, which describes the process whereby less developed countries endeavour to emulate the policies or patterns of development pursued by more developed countries in the hopes of replicating the 'success' the latter experience.

The widespread failure of transitional societies to adopt modern institutions and practices successfully has lead to the view that modernisation operates most effectively through the transformation of institutions or society in general in response to internally generated demands. At the very basic level this transformation is only possible if individuals undergo a "change of heart" - a very complex, intangible process whereby people from traditional societies adopt an "empathetic style of life" (Lerner, 1968:388; Jaffee, 1990:29). Empathy is the psychic mechanism that enables people to imagine themselves in situations other than their own - usually those that are 'worse off'. In the modernisation context there is a 'role reversal' in that people in traditional societies imagine themselves in the positions of people in modern ones, i.e. those that are better off.

The spread of empathy within societies has not been explained, but it is clear that it is often restricted by structural constraints in the form of social organisations and the distribution of material resources; individuals' capacity to exercise a free will may be constrained by their socio-economic position (Jaffee, 1990:34). Nevertheless, Lerner (1968:391) argues that there has been a spread of empathy globally which has diffused new demands for well-being among people who had never been exposed to the idea that well-being was theirs to demand. He says that in order to meet these new demands societies need to undergo comprehensive changes which will enable them to operate more efficiently.

Irrespective of how the diffusion of 'modern' institutions, practices, standards and norms occurs, all theories of modernisation emphasise the importance of structural compatibility. The focus of this idea is on the nature of the relationships of the various parts of society with each other and with the systemic whole. Parsons, when referring to these relationships, uses the term "imperatives of compatibility between structures". Imperatives of compatibility are "those which limit the range of coexistence of structural elements in the same society, in such a way that, given one structural element ... [the other] which goes with it must fall within certain specifiable limits" (quoted in Hoogvelt, 1978:52).

The principle of structural compatibility operates along with the previous two explanations, the picture effect and the empathy effect or as a separate explanation relevant in all societies undergoing change. Not only does the need for structural compatibility determine the direction of change, but it is also central to the success or durability of the change (Hoogvelt, 1978:53).

Proponents of the principle of structural compatibility argue that the simple transfer of institutions, etc. may prove to be positively dysfunctional if other parts of society do not adapt to the new circumstances which arise. Some theories of modernisation go so far as to argue that certain patterns of behaviour are internally consistent to particular economic/technological complexes and that when such complexes are adopted, their associated behaviour patterns send reverberations through the entire social, cultural and political structure of the developing society (Hoogvelt, 1978:56). So, for instance, if the norm of profitability is applied to all resources the institutions, social structures and patterns of behaviour will need to change to allow resources (land, labour and capital) to move from less productive to more productive uses.

Modernisation theories seem to offer a useful framework for analysing the domestic energy transition process. From the above discussion it appears that there are at least three ways of explaining why households shift their energy consumption towards more 'modern' fuels, namely the picture effect, the empathy effect and the principle of structural compatibility.

The picture effect explains the domestic energy transition as the process of change that occurs when less developed or traditional households try to emulate developed household's patterns of energy consumption by adopting more modern fuels. The 'modern' models or pictures of energy consumption to which the less developed households respond/aspire are transmitted/received via channels such as the media, advertising, migrant labour, education and normal contact with urban centres. The most important channel is probably the employment of domestic workers in households that have access to gas and electricity. These workers, in the course of their work, become fully acquainted with the convenience, cleanliness and adaptability of gas and electricity in the domestic situation. It is therefore a small step for them to want the same services from energy in their own households and, in time, to start adopting the more modern fuels.

The empathy effect has a direct impact on the domestic energy transition process by enabling households to imagine that their energy consumption patterns can be similar to those of more developed households and by giving them the confidence to demand that it should be so. This rejection of the status quo and the new demands (wants) it generates provides the impetus that leads to the adoption of more modern fuels. The empathy effect also affects the domestic energy transition process indirectly by creating a demand for improved general standards of living. Improved living standards are only really possible if more resources are made available to households. One of the ways of achieving this is by 'upgrading' the fuels consumed by households. Greater use of gas and electricity simplifies the delivery of resources and leads to greater efficiency of consumption. These changes should translate into better living standards. So imagining oneself into a different situation gives rise to demands for change and sets in motion the trends that eventually lead to change.

The principle of structural compatibility, as noted above, depicts society as consisting of many parts combined into an integrated whole. This implies that changes such as the domestic energy transition process may on the one hand be the product of or at least be affected by other changes in society, while on the other hand it may itself have an impact on those other changes. Stated differently, structural compatibility is relevant in analysing both the causes and consequences of the domestic energy transition process.

With regard to causes of the domestic energy transition process, changes in society such as economic growth, rising incomes, changing technology, increased urbanisation and rising education standards all tend to have some effect. These relationships are examined in chapter 3 in greater detail.

As regards the consequences of the domestic energy transition process, the changes in energy consumption patterns may be regarded as part of the adaptive change in technology that affects households' access to appliances and information, their opportunities for home entertainment and their standard of living generally. Chapters 5 and 6 focus on these relationships.

The three mechanisms of change identified by modernisation theories seldom operate in isolation. Indeed it is most probable that the domestic energy transition process is the product of the picture effect, empathy effect and the principle of structural compatibility operating together - pulling and pushing energy consumption patterns in similar directions. In the following sections, no express attempt is made to disentangle the separate effects of these different mechanisms.

2.3 The energy transition process: conceptual models

The aim of this section is to present a number of conceptual models of the domestic energy transition process. The first two models, namely the energy ladder and income-fuel replacement models, depict the relationship between the energy transition process and income. The third model presented is referred to as the 'modernisation model', since it emphasises the causal relationship between modernisation and energy transition. The final model serves as a standard for the rest of this study, hence its name: the standard model.

2.3.1 Energy transition and income models

The 'energy ladder' model of energy transition is a highly simplified representation of the relationship between the type of fuel consumed by households and their economic status (Doppegieter *et al.*, 1991:33). At the most basic level it is postulated that households will move up a ladder of successively cleaner, more efficient and more convenient fuels as their incomes increase. This succession is depicted in figure 2.2.

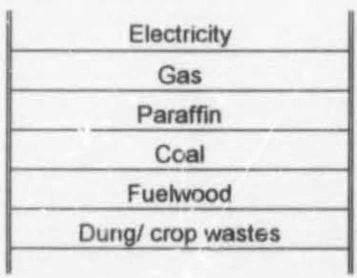


Figure 2.2: The energy ladder

At the bottom of the energy ladder very poor households (which usually encompass traditional households as well) use dung, crop wastes and fuelwood. As the incomes of households rise they can afford to move up to the coal, paraffin and gas rungs of the ladder successively. At still higher income levels households can reach the top of the energy ladder where electricity is the principal energy source.

The main criticism of the energy ladder model is the rigid way it links the use of specific fuel types to particular levels of household income. The relationship between the energy transition process and income is far more flexible than this. The energy ladder also ignores the gradual process of fuel replacement and the phenomenon of multiple fuel use; both integral aspects of the domestic energy transition process.

A more satisfactory model of the relationship between the energy transition process and household income represents the consumption of different types of fuels as a series of bell-shaped replacement curves as depicted in the figure below:

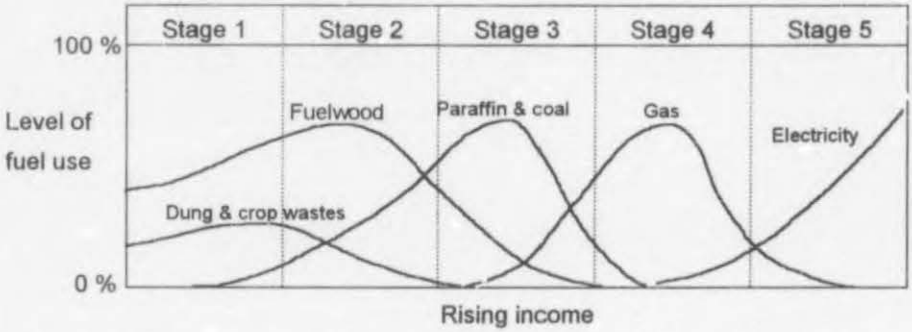


Figure 2.3: The income-fuel transition model of domestic energy transition

The underlying rationale of this 'income-fuel transition' model is the same as that for the energy ladder model, namely that households will consume successively cleaner, more efficient and more convenient fuels as their incomes increase. However, instead of sharp changes from one fuel to another being associated with fixed levels of income, this model allows for gradual fuel transitions and for multiple fuel use. The impact of income on the choice of fuels is also interpreted more broadly, allowing the relative prices of fuels and of appliances to be taken into consideration.

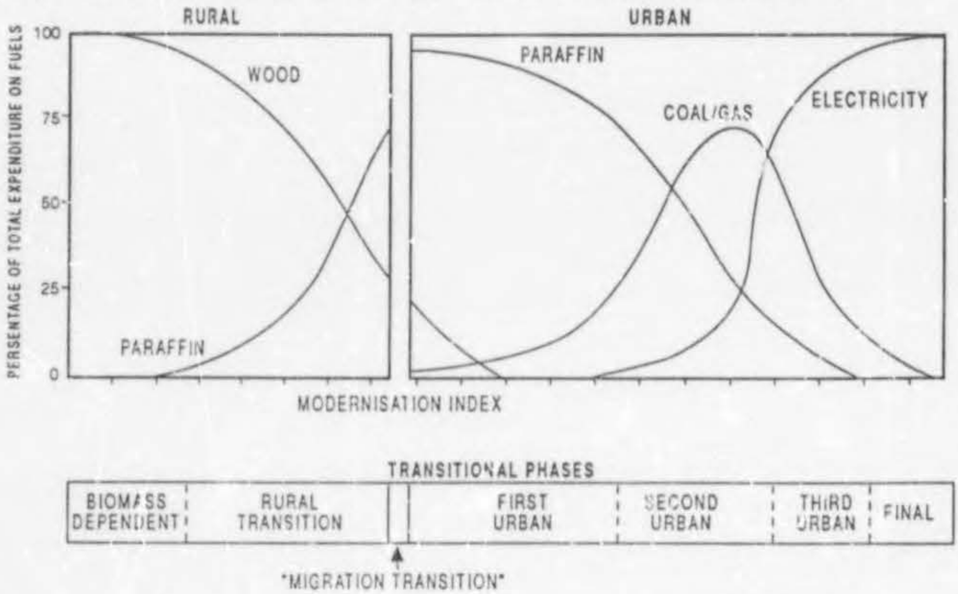
In the above figure it is presumed that at very low levels of income households will only be able to afford non-commercial biomass fuels. In areas where fuelwood is plentiful it will be the main energy source. Where it is scarce and thus relatively expensive very poor families will be forced to resort to burning dung and crop wastes. As income increases, households will be in a position to purchase paraffin which will be used first for lighting in home-made lamps and later, when a stove can be afforded, for cooking. In areas where coal is available and cheaper than paraffin, households will use it instead of fuelwood or paraffin for space warming and cooking. A further increase in income will enable households to purchase gas appliances and substitute paraffin with gas. In the penultimate stage electricity becomes available to households. Initial changes will include the use of electric lighting and radios. The use of electricity for cooking and space warming will require further increases in income, mainly to enable the purchase of the appropriate appliances. The transfer to electric appliances may be delayed for quite some time where household investment in gas appliances has been high. In the final stage of transition electricity will be households' only source of fuel.

The income-fuel transition model takes into account many of the shortcomings of the energy ladder, but its focus is still very limited. In fact, an implicit assumption of both the above models is that other factors affecting energy transition are held constant. But from the discussion in chapter 3 it will become evident that income is only one of many important factors that affect the energy transition process. A more 'encompassing' model is therefore needed to take these other factors into account.

2.3.2 Energy transition and the modernisation model

The 'modernisation' model, developed by Viljoen (1990:125-130), describes the energy transition in terms of the socio-economic characteristics of populations at different phases of the process. These characteristics he summarises in a modernisation index. Unfortunately, when describing the model, Viljoen does not expand on how this index is to be derived, although later he describes a modernisation index compiled from various variables that he found correlated fairly well to energy consumption. These variables include the length of time urbanised, car ownership, residential mobility, type of dwelling, television ownership and whether born in an urban area (Viljoen, 1990:130). It is not clear whether this latter modernisation index is the same as the one referred to in the model. For lack of any indication to the contrary it is assumed that it is.

The modernisation index is plotted on the horizontal axis, while the vertical axis measures the budget shares of fuels, expressed either in terms of useful energy provided by a particular fuel or in terms of expenditure on a particular fuel. Another feature of the model is that it makes allowance for the effect of urbanisation by introducing a discontinuity between the rural and urban components of the energy transition process. The model is presented below:



Source: Viljoen, 1990:125

Figure 2.4: The modernisation model

Since the transition phases identified by this model are broadly similar to the phases identified in the standard model below, they are described here only very briefly.

The biomass dependency phase, the first phase of the transition process, occurs in isolated rural areas where subsistence living predominates. In this phase domestic energy is derived solely from fuelwood, dung and crop wastes. In most areas fuelwood scarcity is a worsening problem.

In the rural transition phase fuelwood remains an important source of fuel, but due to its scarcity it becomes costly to collect, and so it is often cheaper, as well as more convenient, to use paraffin. A transition away from fuelwood also occurs as the general well-being of a region improves.

The first urban transition phase is unconnected to the previous phase as a result of the spatial relocation that accompanies rural-urban migration. For this reason this phase may also be referred to as the 'migration transition'. Due to the extreme scarcity of any form of biomass fuel in many urban areas, and even more so in metropolitan areas, the new urbanites often have no option but to rely almost entirely on paraffin or paraffin and coal.

The second urban transition phase is characterised by a falling rate of dependence on paraffin and greater use of gas, as well as other minor fuels. These changes are seen as part of the search for greater convenience and amenity from appliances and fuels that accompanies the modernisation process. Factors underlying this stage of modernisation are access to formal housing, employment, education and services. The limited access to many of these factors means that many people may be trapped in this phase.

The third urban transition phase sees the beginning of the process of electrification. The shift to electricity, due to its convenience, results in a decline in the use of paraffin, coal and gas - although gas remains dominant. The rate of transition is largely dependent on the availability of electricity, i.e. the rate of electrification, yet other factors such as the cost of appliances, the availability of formal housing and the cost of hook-up are also important.

In the final phase of energy transition electricity becomes the only domestic energy source of importance. Further changes relate mainly to the quantity of electricity used. The trend is for consumption to increase as households accumulate appliances and become more affluent, although there is also evidence of a minuscule shift to devices that use renewable resources such as solar heaters, especially among households in the top income group.

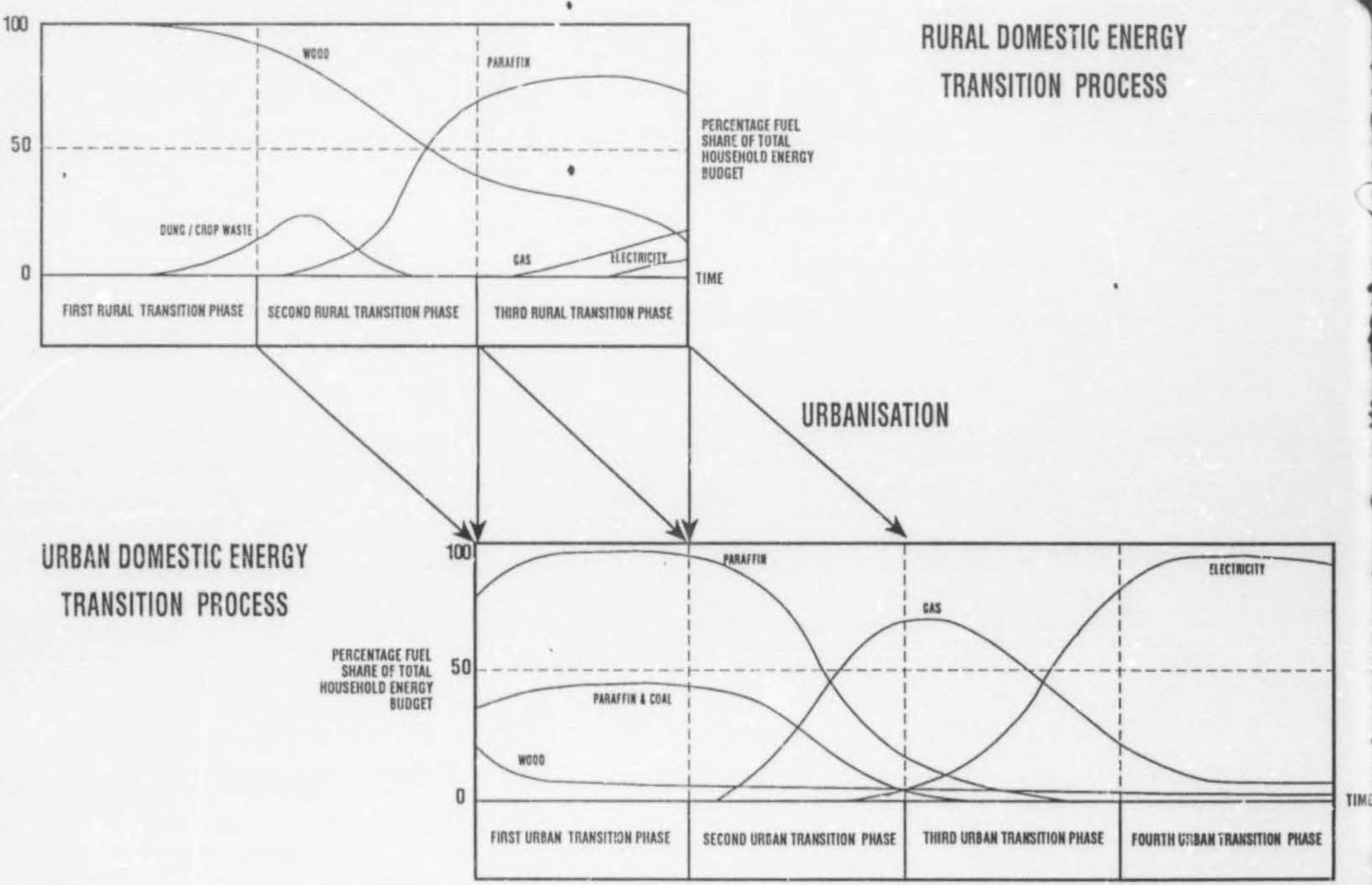
On the whole the modernisation model gives a good description of the domestic energy transition process. Nevertheless, some general comments on it are in order: firstly, if the modernisation index used in the model is the same as the one described in Viljoen (1990:130) then it gives rise to both terminological and conceptual problems. Using the term "modernisation" creates associations with a specific tradition of social analysis that attaches a far broader meaning to the term than Viljoen's index indicates. The term is therefore misplaced or wrongly defined. With regards to the compilation of the index itself, it includes variables such as place of birth or time urbanised, that apart from being very area specific are only remotely connected to household energy use. It also omits some important variables of modernisation, e.g. education. In addition, the index does not make provision for the important effects that variables such as fuelwood scarcity, the availability of paraffin and electricity and the price of appliances have on the transition process, although these are referred to in the discussion of the individual phases. Secondly, the use of an index that does not change during the course of the transition process tends to hide the fact that in each phase of transition different factors are at work affecting its direction and pace. Thirdly, there does not seem to be any rationale behind the relative 'amounts' of modernisation apportioned to each transition phase, i.e. why do the phases as represented on the horizontal axis differ in extent? Fourthly, the budget shares of fuels are only a meaningful measure of the relative use of different fuel types if all fuels are commercialised or if equivalent prices are given to the 'free' biomass fuels. As an alternative the percentage shares of fuels in households' total energy budgets could be used. Lastly, the dynamic nature of the transition process is not immediately evident from the diagram, which is supposed to be a representation of the process over time.

2.3.3 The standard model

The model presented below is referred to as the standard model because it serves as a 'standard' for the rest of this study and because it attempts to summarise the relationship between the domestic energy transition process and the economic, demographic, spatial and temporal factors discussed in chapter 3 as completely as possible. It should be noted that despite the visual similarity with both the income-fuel transition model and the modernisation model, the variables measured by the axes of these models differ and many more causal factors are taken into consideration.

The standard model depicts the energy transition in rural and urban areas separately. The transition process in rural areas is divided into three phases and that in urban areas into four. The model also shows how rural-urban migration is likely to affect the migrant household's energy consumption patterns.

Figure 2.5: The standard model of the energy transition process



In the standard model the vertical axes measure the percentage shares of fuels in the total household energy budget in terms of the useful energy provided by each fuel. This measure is regarded to be preferable to a measure based on the fuel shares of energy expenditure because it reduces the possibility of under-representing non-commercial fuels, which are important sources of energy in the early stages of energy transition. Calculating useful energy shares is, however, not without problems: apart from the scarcity of data on fuel use, there is, firstly, the question of which conversion factors should be used to calculate the potential energy output (or nett energy content) of different fuels and, secondly, the question of which set of appliance efficiency ratings should be used to convert the nett energy supplied by each fuel into 'useful energy'. Various measures exist in each case. The choice of measures could influence the relative importance of fuels at different stages of the transition process. These practical problems are not addressed here; instead hypothetical values are used for the purposes of illustration.

Time is reflected on the horizontal axis so as to emphasise the dynamic nature of the energy transition process and to provide a context in which the other factors can interact with each other. While the passage of time certainly does affect the transition process, its position on the horizontal axis is not intended to reflect a causal relationship. Since the different phases of transition may occur more or less slowly, the specification of an appropriate time period for each phase has been deliberately avoided. Instead, the transition time of each phase is assumed to be equal for the purposes of illustration. in reality, there is a considerable degree of spatial and intertemporal variation in the rate of transition between the different phases and across the process as a whole.

The discussion of the above model is carried out under various headings: the role of rural-urban migration, differences between the rural and urban transition processes, the rural transition phases and the urban transition phases.

2.3.3.1 The role of migration

Essentially the standard model presents two processes of energy transition. They are separated spatially and consequently progress more or less independently. Nevertheless, certain factors do create links between urban and rural areas.

Factors operating in the urban-rural direction include labour migrancy and migrants' remittances, extension of energy distribution networks, modernisation, the availability of appliances and the changing of people's preferences. The influence of these factors is discussed under the relevant phases they affect.

The most important factor operating in the other direction is rural-urban migration. This process is illustrated in the standard model by the lines between the rural and urban transition phases of the model. The lines suggest which urban transition phase a rural migrant or household coming from a specific phase in the rural transition process is most likely to slot into when moving to an urban area. Migrants moving out of the first and second rural energy transition phases are likely to transfer into the initial urban phase of energy transition, because their level of income, access to formal housing and other socio-economic characteristics will be broadly similar to urban dwellers in this phase. A few migrants from these early rural phases may be able to move directly into the second or even third urban phases, but as in the case of urbanites this will depend on their incomes, the availability of fuels other than paraffin and the other factors mentioned below under the respective phases of transition. By the same token, migrants from the third rural transition phase are likely to join the urban energy transition process in either the second or later phases, because their socio-economic characteristics are similar to the urbanites in these phases. In addition, energy consumption patterns in the third rural phase are fairly similar to those in the second and third urban phases of transition.

Migration in the standard model is assumed only to affect the energy transition process experienced by the actual individuals or households that move from rural to urban areas. They are forced to adapt their energy consumption patterns in response to the new factors prevailing in the urban areas to which they move. However, for the many households that either remain in rural areas or are of urban origin anyway, the pattern of energy transition remains relatively constant. If the rate of migration or of urban growth is particularly rapid it may affect the relative importance of different fuels in the national energy budget, as well as retard or slow down the energy transition process experienced by a region or the country as a whole, but it is assumed that its basic pattern will remain constant.

This treatment of the migration process's effect on energy transition differs from that in the modernisation model. In the latter model, migration is seen as an integral part of the transition process. The first urban transition phase is even referred to as the migration transition. The modernisation model emphasises the process of energy transition experienced by individual migrants or migrant households. For them the spatial relocation that migration entails does, in most instances, result in a "discontinuity from the previous stages of the process" (Viljoen, 1990:128), a circumstance clearly indicated by the break in the energy transition pattern depicted in the modernisation model. This is an important point to make, but a far greater number of households either do not migrate or are urbanised already. In their cases no migration transition occurs. Instead, they continue to be exposed to the factors that affect the transition process in the areas where they have always been. Unfortunately this is not immediately clear from the modernisation model, which is why the standard model depicts two separate transition processes and links them via the migration process if and when it occurs.

2.3.3.2 Rural versus urban transition processes

To understand the above model it is necessary to highlight some of the differences between the rural and urban transition processes depicted in it.

Some of the differences are immediately apparent: the importance of fuelwood in the rural transition process versus the almost total absence of fuelwood use in any of the urban transition phases; the dominance of commercial fuels in urban areas versus the availability of non-commercial fuels in at least the early phases of the rural transition; and the greater mix of fuels in especially the third urban phase than in any of the rural transition phases.

The differences that are less obvious are, however, of greater interest: firstly, in rural areas poor households' main source of energy is fuelwood or other biomass fuels, while in urban areas it is paraffin or coal (where it is available). This means that the urban poor generally need access to cash incomes in order to meet their energy requirements, whereas the rural poor, at least in the early phases of transition, can meet their needs from a 'free' resource base. In the later phases of the rural transition process even fuelwood becomes commercialised in response to its increasing scarcity.

Secondly, the rate of energy transition in the rural areas is usually far slower than that in urban areas. So while the urban energy transition process may take place over a period of years or decades, the rural transition process may take scores of years or even generations. Where the transition is very gradual energy consumption patterns may be regarded as stable for all practical purposes. The reasons behind these differing rates of change are manifold: the low levels of economic development and growth, the strength of traditions and limited access to new technologies all retard change in rural areas, while the impact of modernisation, greater economic and political power and the bias in the provision of energy services and in the extension of distribution networks accelerate the changes in urban areas. Probably the root difference is the greater population density in urban areas which not only leads to the more rapid depletion of the biomass energy resource base, but also makes the creation of alternative energy networks more economical.

Thirdly, the amount of energy consumed in the later phases of the urban transition process is usually far greater than that consumed in any of the rural transition phases. The difference may be ascribed to the higher incomes of urban households and the greater versatility, convenience and amenity of fuels, particularly electricity, used in urban areas, as well as the fact that fuels are readily available, if not 'on line', in urban areas. However, in the early phases of the urban transition process households generally consume less nett energy than in the first phase of the rural energy transition process, before fuelwood scarcity becomes a constricting factor.

Reasons for this apparent inversion of the predominant trend toward greater energy use in urban areas are discussed below.

2.3.3.3 The phases of energy transition

These descriptions of the phases of the domestic energy transition process highlight the following aspects: the dominant energy sources used, the level of energy consumption and trends in the level of energy use and the rate of transition.

(a) *The rural transition phases*

(i) *The first rural transition phase* Domestic energy consumption patterns in rural subsistence areas have been stable for very long periods of time and under normal circumstances would show little tendency to change. Households rely almost exclusively on fuelwood and access to it is 'free'. In most rural areas other biomass fuels - dung and crop wastes - are available, but very little is used, since people invariably show a preference for fuelwood. Other fuels, such as paraffin, are either not available or unaffordable since households' cash incomes are very low. Affordability also restricts the use of more efficient wood stoves, although cultural factors may limit their use as well. Where candles and paraffin (for lighting) are used they usually account for a major share of energy expenditure (within a very limited budget), but in terms of the useful energy they provide they are insignificant. In this pre-transition phase an average household consisting of six people will consume between 9 and 18 GJ of useful energy per year, depending largely on the geographical location and climate. Seasonal variations in energy consumption may also be significant.

It is only when fuelwood resources start to become scarce that change in the status quo occurs. The first noticeable sign of energy transition usually entails households supplementing declines in their fuelwood consumption levels with lower grade biomass energy sources such as dung and crop wastes. When this happens the quantity of energy used by households may fall due to the need to conserve fuel and due to the lower energy efficiencies of dung and crop wastes. Energy consumption levels may decline to the bare minimum. This initial phase of the transition process will be very gradual, but it will tend to gain momentum as fuelwood depletion progresses.

(ii) *The second rural transition phase* At the beginning of the second phase of the rural energy transition process depicted in the model, fuelwood is still the predominant source of energy. However, as this resource diminishes, households have little option but to make greater use of dung and crop wastes, either until these fuels also become depleted or until they can afford an alternative such as paraffin. Only the poorest households will continue to use dung and crop wastes after paraffin becomes available, hence the gradual decline in the importance of these energy sources. The transfer to paraffin is hastened by the commercialisation of fuelwood, which reduces differences in the relative cash price between the fuels. Towards the end of the second rural transition phase paraffin should become more important than fuelwood.

As far as the quantity of energy consumed is concerned, it will tend to remain at very low levels throughout this transition phase, unless rising household incomes enable greater expenditure on commercialised energy sources.

The rate at which the changes noted above take place varies from region to region and according to the relative strength of the factors affecting the process. These factors include the scarcity of fuelwood, increasing incomes, the availability of paraffin, the cost of primus stoves and the processes of modernisation and economic development occurring in the area.

(iii) *The third rural transition phase* In the third phase of the rural energy transition process, the fuel consumption patterns of individual households will vary considerably. Some households will adopt commercial energy sources almost completely and others use a mix of fuels. The overall pattern will continue to reflect the trends set in motion in the previous phases, but the changes will tend to be less pronounced. So fuelwood's share in the total household energy budget will continue to decline, while that of paraffin continues to increase gradually. As the transition process progresses with the adoption of gas and electricity, paraffin's share in total household energy budgets may even begin to decline. However, use of gas and electricity in rural areas is usually restricted to specific households and so the impact on total household energy consumption is limited. The use of stand-alone petrol or diesel generators to supply electricity to households may also become more common in this phase of transition, but by no means widespread.

The average quantity of energy consumed by households in this phase is likely to be slightly higher than in the previous phases, both because household incomes are likely to have increased and because households will have had time to become familiar with the characteristics and uses of the new fuels, in most cases paraffin. The amount consumed may vary widely from household to household according to factors such as the specific household's income, the household's level of modernisation, the predominant type of energy source or the mix of fuels being used, and the size of the household.

The rate of energy transition in this phase is likely to be slow compared to the changes which occurred in the phase preceding it. The main factors restricting the pace of change are the limited availability of gas and electricity, the level of household incomes and the proximity of the region to major urban centres. The latter factor will tend to determine the region's level of modernisation, income and access to the electricity grid and gas supply networks.

A fourth phase of rural energy transition could be postulated. As in the fourth phase of the urban energy transition, electricity would be the predominant energy source. However, the likelihood of such a situation being reached in the short or even the medium term is rather remote in many rural areas in South Africa. It is expected that the trends that constitute the third phase of energy transition will operate over a long period.

(b) *The urban transition phases*

Just as an extra phase could be tagged onto the end of the rural transition process, so could a phase that would precede the first phase of the urban energy transition process be identified. It would be similar to the second rural phase of transition. However, in most of South Africa's large urban centres, biomass fuels were depleted a long time ago, with the result that the energy consumption patterns depicted in what is described as the first phase of the urban transition process in this model has been the norm for an equally long period of time.

(i) *The first urban transition phase* Patterns of energy consumption in the first phase of the urban energy transition process are fairly constant although they tend to differ spatially. In areas where coal is available, most households use about equal quantities of coal and paraffin, which together then account for most of the energy consumed by households. By contrast, in areas far away from the sources of coal, paraffin is the predominant fuel. Indeed, in certain areas the reliance on it may be almost total. In both areas fuelwood consumption is minimal, although it is likely to be higher in coal consuming areas where it is used as kindling for coal fires.

The quantity of nett energy consumed in this first phase is usually lower than in the first and second phases of the rural transition process, but the amount of useful energy that is available to the household is often greater because of improved efficiencies in both the types of fuels and the appliances used. Nevertheless the nett levels are extremely low. The quantity of energy consumed is again dependent on a variety of factors: the household's income, the level of modernisation and size of household. Each of these factors will tend to increase energy consumption.

(ii) *The second urban transition phase* Changes in energy consumption in the second urban energy transition phase are very significant compared to those in the previous phase. At the beginning of the phase paraffin is still the dominant fuel, but with the passage of time there is a transition away from it and towards gas. As shown in the diagram the transition may be very rapid - even more rapid than the rural transition that led to the abandonment of fuelwood and the adoption of paraffin. At some stage gas may become the dominant source of energy, but it is unlikely to become as dominant as paraffin in the previous phase. Instead a household will meet its energy requirements with a mix of energy sources. Major fuels will include gas, paraffin and coal (depending on location), while very small amounts of energy may be derived from fuelwood, candles, dry cell batteries and from car batteries.

While paraffin may lose its predominant position in the household energy budget, the consumption of paraffin will tend to increase. Indeed, total household energy consumption will rise as households start to earn incomes that enable more than mere subsistence consumption, and as they start to use gas which is a more convenient form of energy. Also growing familiarity with the different fuels and their uses will tend to encourage higher energy consumption.

(iii) *The third urban transition phase* In the third phase of the urban energy transition the trends noted in the previous phase continue. Paraffin continues to decline in importance, being replaced by gas and eventually by electricity. At the beginning of the phase gas is the dominant fuel, with its share of the total household energy budget reaching a peak just before electrification really becomes a significant factor. As electrification gets under way the dominance of gas in the total household energy budget starts to decline, but this does not necessarily mean that gas consumption decreases - at least not at first. It is only when electricity starts to replace gas as an energy source for cooking that the use of gas starts to decline in nett terms. Before such a time the services provided by electricity tend to complement those provided by gas.

As noted in the discussion of the second phase above, total household energy consumption will tend to increase with income, with access to more convenient energy sources and with growing familiarity of the fuels and their uses. In the case of electricity, consumption is closely related to the number and type of appliances that a household possesses. Since it usually takes time for a household to accumulate appliances, electricity consumption should show a rising trend for some time before levelling off.

(iv) *The fourth urban transition phase* The fourth phase of the urban energy transition is characterised by the dominance of electricity. Indeed the percentage share of electricity in the total household energy budget in this phase is comparable to that of paraffin in the first urban phase noted above. The consumption of other fuels is restricted to specialised functions such as the use of firewood for space heating, gas for braais and paraffin and candles as back-up sources of lighting in the event of a power failure.

The quantity of energy consumed in this phase is not quite as closely linked to incomes as in previous phases; nevertheless income levels are still important. The higher a household's income, the less sensitive it is likely to be to factors such as the cost of electricity and the cost of appliances. Households with moderately high levels of income are still likely to take such factors into account, especially when it comes to the purchase of expensive appliances such as refrigerators.

There is also some correlation between the length of time which a household has access to electricity and the quantity of electricity consumed. However, it does not appear to be a causal relationship; rather it is during this time that a household accumulates more appliances and becomes acquainted with the fuel's uses, as well as develops energy intensive habits. These changes are probably best interpreted in terms of modernisation.

Finally, at some stage after electrification, households may start to seek ways of reducing their dependence on electricity or of reducing their energy consumption by investing in alternate energy appliances such as solar water heaters. The extent to which these appliances are used depends on their price and the awareness of the need to conserve energy or, more generally, on the extent of environmental socialisation that has taken place. The initial effects of this shift towards other energy sources is depicted in the diagram by the slight downward trend in the share of electricity in the total household energy budget towards the end of the of the fourth phase of the urban transition process.

It is possible to postulate a fifth phase of energy transition where the use of energy saving appliances and energy conservation in general becomes important in household energy consumption patterns. In the USA there have been concerted efforts to change household energy consumption patterns in this direction. Gore (1981:30-57) discusses some of the initiatives that have been undertaken in different areas. However, South Africa still has to progress a long way before the domestic energy transition process enters such a phase.

2.4 A framework for comparisons

At its simplest the problem on which this study is trying to caste some light may be represented as follows:

Socio-economic states	1	2
Household welfare derived from energy use	X	Y
Change in welfare due to transition from 1 to 2	Y - X	

Figure 2.6: Measuring changes in household welfare

Households in socio-economic states 1 and 2 have differing patterns of energy consumption that enable them to attain welfare levels of x and y respectively. A household whose energy consumption pattern makes a transition from that typical of state 1 to that typical of state 2 will experience a change in household welfare equal to y-x. If y-x is positive, reflecting a rise in welfare, then the transition may be regarded as desirable and other households should be encouraged to make it. If it is negative the transition was undesirable and the process should be discouraged or possibly even reversed. The above example can be extended so as to fit the framework of the standard model of the domestic energy transition process:

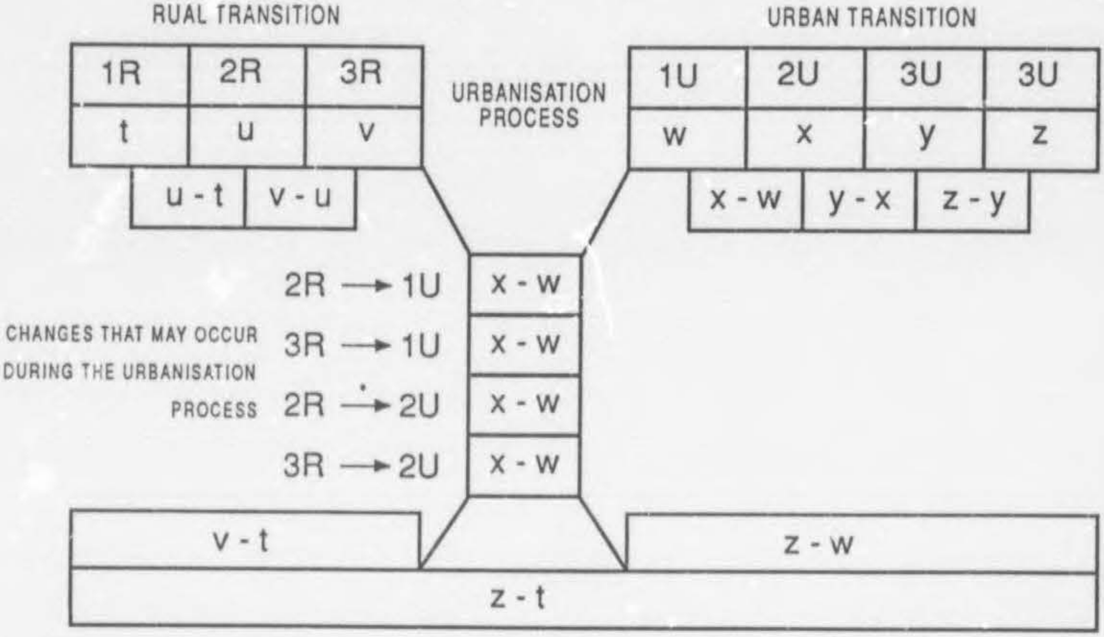


Figure 2.7: Measuring changes in welfare across the domestic energy transition

The interpretation of this figure is basically the same as for the previous one: a household whose energy consumption changes, say, from pattern 2U to 3U will experience a change in household welfare equal to y-x. If y > x then the change is desirable, but if y < x the reverse applies. In this figure:

- the number of socio-economic states (3 + 4) is determined by the number of transition phases depicted in the standard pattern of domestic energy transition;
- the set of changes between the rural and urban transition processes depict welfare changes that may occur as household energy consumption patterns change during/as a result of the urbanisation process. For instance, if as part of such a process a household's energy consumption pattern changes from that typical of 2R to that of 1U

then the household will experience a change in welfare equal to w-u. The four most likely combinations of change are given, but others are possible;

- the bottom two lines of the table show the change in welfare levels from the beginning to the end of the rural and urban transition processes respectively and of the two processes combined. This broad view is important because while the transition from say 1R to 2R may lead to a decline in household welfare, the welfare effect of the entire rural transition process (from 1R through 2R to 3R) may be positive, i.e. u-t may be less than v-t. So a transition from 1R to 2R may be undesirable, but the same cannot be said of a transition from 1R to 3R.

The actual application of this framework to the analysis of levels of household welfare derived from different patterns of energy consumption would entail at least six steps:

(i) the collection of information on the effects that energy use have on household welfare levels in each transition phase, i.e. the determination of welfare levels t, u, v etc.;

(ii) the comparison of the welfare levels in adjacent transition phases, e.g. u - t;

(iii) the comparison of welfare levels across the urbanisation process;

(iv) the comparison of welfare levels across the rural and urban transitions and across the entire domestic energy transition process;

(v) the determination of which transitions are desirable and which are not, based on the results of the above comparisons; and

(vi) the formulation of recommendations (policies) to change household patterns of energy use so as to enhance their welfare.

This framework and procedure may appear well suited to the task in hand, but unfortunately it is completely impractical on a number of counts. These are noted briefly. Firstly, it is implicitly assumed that levels of welfare can be known exactly and expressed by a single variable or at least a function. This is a gross over simplification. Welfare, as is clear from section 1.2 above, is a complex concept affected by many factors that interact with each other in complex ways. A means of measuring welfare from all these sources does not exist, since a common unit of welfare is lacking and some welfare producing actions are simply not amenable to measurement. Secondly, the framework and procedure are based on the standard pattern which places the analysis in a straight-jacket. The standard pattern is just one attempt to portray the domestic energy transition process and as such it is a simplification of reality. This means that patterns of energy use that are different from those portrayed in the standard pattern are not 'deviations', but reflect the limitations of the standard pattern. A more 'open' analysis allows different energy use patterns to be treated on their own terms. Thirdly, there is not sufficient data to make even rudimentary estimates of welfare levels in each of the seven phases of transition. Even the data that exist are not often comparable. Lastly, using this framework would require a vast amount of repetition, which would make the study far too long.

CHAPTER 3

CAUSES OF ENERGY TRANSITION

Study of the domestic energy transition process has to date focused on identifying the causes or factors that precipitate the process. While much has been learned it does not seem possible to identify from the literature a single precipitating factor, or even a predominant factor. Instead numerous real or potential causes have been noted.

This chapter examines the factors that have been identified or are widely regarded as causes of the domestic energy transition process. By way of introduction factors that could conceivably determine changes in total energy use are noted in section 3.1. Then the factors with specific causal effects on the domestic energy transition process are discussed (section 3.2). Some of these factors have a definite economic content, such as income, prices of energy sources and the cost of appliances, while others have a broader developmental or social content, e.g. urbanisation, type of dwelling, attitudes and preferences. From the range of factors it is clear that the domestic energy transition process is not only or even predominantly an economic phenomenon. Lastly, section 3.3 looks at the operation of these factors within the framework of the standard model described on section 2.3.3. The aim is to identify those causal factors that impact on the progress of the domestic energy transition process during each of its phases.

Although the different causative factors are discussed separately they are, in fact, all interrelated, each factor complementing or detracting from the others according to the principle of structural compatibility. The theories of modernisation discussed in section 2.2, thus, help explain not only the relationships between the domestic energy transition process and the causative factors, but also between the latter factors themselves. Change in any sphere of society causes greater or lesser reverberations in all the other spheres.

3.1 Factors determining changes in total energy demand

The domestic energy sector is a component of the total energy sector. Therefore, factors that affect the latter are also relevant to the former. At the theoretical level, Leach *et al.* (1986:11-12) suggest that changes in total energy use may be decomposed into the following causal relationships and effects:

- different sectoral growth rates: these are measured in terms of GDP growth and are basic to the changing level and structure of energy demand in economies;
- income-induced changes in energy consumption: a shift in the level and distribution of income may lead to changes in the level and fuel mix of final energy consumption in the domestic sector, as well as other sectors;

- growth-induced changes in product mix: while growth may change the mix of major sectors, it may also lead to changes in the "product mix" within sectors, for instance the mix in types of housing;
- energy price-induced changes in product mix: real increases in energy prices may lead to a change in product mix, e.g. less energy intensive products are substituted for more energy intensive ones;
- autonomous technology substitution: growth allows the progressive replacement of more energy intensive equipment with 'better', more energy efficient technology;
- energy price-induced technology substitution: rising costs lead to the substitution of more energy efficient, capital intensive technologies for energy intensive technologies; and
- energy price-induced fuel substitution: changes in the relative prices of fuels may lead to changes in the relative fuel shares.

This list is by no means exhaustive. Many non-economic factors are not included, as is evident from the rest of this chapter. The relationships, outlined above, are also not as straight forward as stated. In reality, the adaptation processes are slowed down by a number of economic, social and cultural restrictions, conflicts of goals and resulting political friction, as well as limitations due to inadequate infrastructure. These problems are referred to in greater detail in the following sections.

3.2 Causes of the domestic energy transition process

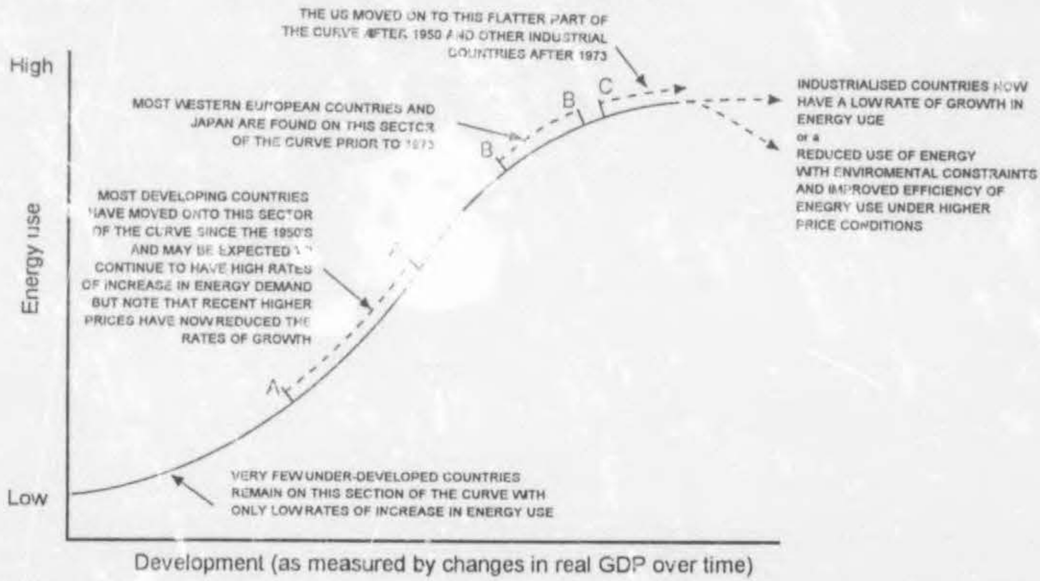
This section examines factors that have been identified in the literature as causes or precipitating factors of the domestic energy transition process. Though each factor is dealt with separately, it must be emphasised that all are interrelated and it is their combined operation that moves the domestic energy transition process forward. The order in which the factors are discussed is not related to the importance of their impact on the transition process.

3.2.1 Economic development

The general connections between economic development and energy consumption have been extensively studied by economists and energy planners. The relationship has been expressed in many ways, two of which are looked at here, namely, energy-intensities and energy-elasticities.

Energy intensities measure the amount of energy consumed per unit of GDP produced, i.e. E/GDP. Data on long-term energy-intensities in the USA indicate an increase up to a certain point followed by a downward trend. This pattern is also reflected in data of energy-intensities in developing and OECD countries since 1973. It would thus appear that "in the early stages of economic development a tendency exists for increasing energy-intensity followed by a decrease as higher levels of economic development are reached" (Doppegieter *et al.*, 1991:270). The reason for the decrease is ascribed to improved technologies, more efficient fuels and greater productivity (Leach *et al.*, 1986:20). Gerholm (1992:27) is critical of the relevance of this measure because it combines economic (GDP) and physical (E) units of measure and because the ratio can be affected by a range of technological and economic developments and measures. Some economic measures may be unrelated to energy use, e.g. improvements in labour productivity.

Energy-elasticities measure the relationship between energy consumption and economic growth as determined by the ratio change in energy use to change in GDP. This ratio is also known as the "energy coefficient". The figure below summarises the general trend underlying the energy-elasticities of countries as their economies develop over time.



Source: Doppegieter *et al.*, 1991:273

Figure 3.1: The relationship between energy-elasticities and countries' economic development

The S-shaped curve can be divided into three stages as shown. Stage A is characterised by energy-elasticities exceeding one, representing most developing countries; in stage B energy-elasticities are about one, which was typical of most West European countries and Japan up to about 1973; and stage C, with energy-elasticities smaller than one, represents most industrial countries since the first oil crisis. So, broadly speaking, "the rate of change in energy use is a function of the stage of economic development" (Doppegieter *et al.*, 1991:269).

Leach *et al.* (1986:14) note that "in subsistence societies energy use is almost entirely for consumption purposes, i.e. for household use" and that "the traditional development process introduces an expanding range of activities and technologies which greatly increases the use of inanimate energies for production purposes. In the residential sector, however, energy use may fall as families switch to more efficient cooking and heating fuels and associated equipment." Cecelski *et al.* (1979:2-3) note that development plays an important indirect role: "increases in income accompanying economic growth would lead both to rises in household energy consumption and to changes in the composition of that consumption." Even a policy emphasising basic needs would increase both the derived demand for energy as effective incomes rise, and the use of energy embodied in such services. However, it is not at all clear how or to what extent these trends affect the domestic energy transition process.

Foley (1981:89) notes that "energy consumption and GDP production are so enmeshed in the geographical, industrial, economic, social and political characteristics of countries" that to try and associate trends with a specific process such as the domestic energy transition is almost impossible. It nevertheless seems reasonable to argue that, due to the need for structural compatibility (i.e. the need for different structural elements of a society to be able to coexist), development (whether economic or otherwise) does have an impact on the domestic energy transition process.

3.2.2 Income

The energy transition process is most often analysed in terms of rising incomes. Typical findings are that: "(1) there is a very strong relationship between energy consumption and income; (2) this relationship is different for rural and urban areas, with greater consumption in the rural category; and (3) there is a marked tendency for consumption to saturate at high-income levels" (Leach *et al.*, 1986:148). Data supporting these findings are certainly not lacking. At the macro level, Viljoen (1990:43) finds that there is a negative correlation between fuelwood use and GDP per capita which, he argues, suggests that the transition from this energy source is at least partly dependent on the creation of wealth. Leach *et al.* (1986:143-145) note that biomass dependence falls very sharply with increased income and is replaced by greater reliance on commercial fuels. They argue that this shift may lead to a fall in total fuel consumption, but due to differences in end-use efficiency of the replacement fuels the quantity and quality of energy services may increase.

At the household level Viljoen (1990:80) argues that "the budget share of expenditure rather than share of income" is a better indicator of the transition process. Moreover, he finds only a weak correlation between income and expenditure on the major fuels. In the case of electricity, evidence from a small survey in Langa and Guguletu suggests that income does not determine electricity consumption. It is therefore suggested that "the causal role generally ascribed to income in influencing expenditure (and hence consumption) on fuels cannot be supported" (Viljoen, 1990:92 and 122). Where there is some correlation Viljoen argues that the changes are determined by different factors at each level of income and not by income itself. At low income levels household expenditure is found to be a key variable, while for groups with incomes above R100 per week (1987) household expenditure is said to have little effect; non-economic variables are found to be important instead. On the other hand, when Viljoen (1990:106) divides his survey sample into groups according to the predominant fuels used it is found that income increases across the groups in the following order: paraffin, mixed, gas and electricity. This appears to confirm the impact of rising incomes on the domestic energy transition process.

Levels of income are not the only relevant income related variable. In section 3.1 it was noted that energy consumption patterns may also be affected by changes in the distribution of income. Cecelski *et al.* (1979:63) note that "existing patterns of income distribution and ownership strongly condition access by the poor to energy resources." This matter has not been studied sufficiently to come to any firm conclusions. Superficial evidence, nevertheless, suggests that in societies with very skew income distributions the energy transition process in the poorer communities is inhibited, since they do not have the means to demand access to or to purchase commercialised energy sources, particularly electricity. Their competitive position is weak due to the unequal distribution of income. This is obviously directly relevant to South Africa.

3.2.3 Price of fuel

Fuel prices and the cost of energy services affect the level of energy consumption both directly and indirectly, while relative fuel prices tend to influence the choice of fuel used and the rate of interfuel substitution (Leach *et al.*, 1986:63-64).

"In the literature, the quantity of energy consumed by the poor is frequently described as 'inelastic' in the sense that it is a basic necessity which must be provided under all circumstances"; this implies that energy consumption is not responsive to price changes (Cecelski *et al.*, 1979:22). It would appear that this is true at low levels of income where a fairly fixed level of nett energy is maintained - about 10 GJ per capita annually, which is considered to be barely sufficient to meet basic needs (Cecelski *et al.*, 1979:34). Where households are already living at the energy 'bread-line' or poverty line, higher fuel prices may lead to severe hardship; households may have to cook fewer meals or the meals may be undercooked; living-spaces may become extremely cold; and activities may be restricted to daylight hours. At higher levels of income households have more scope to save on their nett energy consumption and so, above a certain threshold amount, energy consumption will tend to be more price elastic. For instance, since the first oil shock in the early 1970's, households in the USA have been able to reduce their energy consumption significantly without affecting their standard of living in response to the rising cost of energy (Gore, 1981:34). As regards individual energy sources, they tend to be more price elastic than energy *per se* given the scope for inter-fuel substitution.

Energy prices affect the consumption of energy indirectly by influencing the technology choices. High prices will tend to encourage the use of energy efficient appliances and the construction of energy efficient houses, or at least the effective insulation of houses. Poor households are, however, generally less able to take advantage of these changes and so "suffer most from the rising cost of energy" (Gore, 1981:57).

In rural and peri-urban areas paraffin, coal and gas are the only practical alternatives to biomass fuels for cooking and heating. The ratio of the useful energy versus the cost of energy derived from paraffin, coal or gas to that derived from fuelwood is, therefore, extremely important to the issue of interfuel substitution or energy transition in these areas. The lower the ratio, the more widespread the use of the non-biomass fuel is likely to be. Where fuelwood is collected by consumers, the real costs should be used to calculate the ratio. (Factors affecting the real price of fuelwood are discussed below.)

The relative price between coal and paraffin appears to be the main differentiating factor between these two fuels. This price difference has given rise to the dominance of coal use in Gauteng and Mpumalanga versus the dominance of paraffin in the Western Cape (Viljoen, 1990:60).

The perceived price of different fuels is also important in determining the pattern of energy consumption. In a survey on attitudes towards different fuels Viljoen (1990:112) found that the "widespread usage of paraffin is ... a result of its perceived economy". Whether this is still the case is not known. The perceived costs are also relevant with regard to collecting 'free' biomass fuels. In a study of domestic energy in the former KwaZulu, Gandar (1984:3, 6) found that women who collected wood, in addition to the time cost (which averaged between 6 hours 45 minutes and 9 hours per household per week), also noted the difficulties (long distances, heavy loads and steep terrain), the inconvenience (going out in the rain or when ill), and the risks (of molestation). These factors, as well as the environmental impact of gathering wood, all increase the real cost of fuelwood. "Another factor is that the real cost of collecting fuelwood and dung appears to be borne largely by those groups - women and children - whose alternative occupations are particularly limited" (Cecelski *et al.*, 1979:28). Due to discrimination against women on the grounds of sex this may be true as far as cash earning opportunities are concerned. However, it is more likely that women have to bear the brunt of collecting wood and other domestic chores because of their inferior status in patriarchal societies (Wilson and Ramphele, 1989:177).

Factors affecting the relative prices of fuels include the availability or scarcity of the respective fuels (discussed in section 3.2.5), the existence of price subsidies for certain fuels such as paraffin, the cost of changing to a new energy system (i.e. hook-up costs and appliance prices) and the volume of fuel that needs to be consumed to make it economical. With regard to the last point, paraffin is easily divisible and so while buying in bulk may be cheaper than in small quantities, the difference is not substantial. By contrast, it is cheaper to supply electricity to large consumers than to small consumers. The poor, if linked to the grid, do not have the means to consume large amounts, so unless there is cross-subsidisation between large and small consumers, the price of electricity to the poor will be higher.

3.2.4 Cost of appliances

Closely related to the impact fuel prices have on the domestic energy transition process is the cost of appliances that make the utilisation of new energy sources possible. The effect appliance prices have on the energy transition process may be characterised as follows: if a household cannot afford the critical outlay on appliances to utilise a particular energy source, then that household will be barred from making the transition to the fuel, even though in the long term it may be more efficient and economical. As Cecelski *et al.* (1979:28) note: the "high first cost of a new system (such as an improved wood burning stove) may continue to inhibit widespread adoption, even at higher income levels." This is particularly relevant in the case of electricity where, in addition to the cost of appliances, there are usually installation and connection fees.

No appliances are needed to use fuelwood, so apart from a pot, the initial outlay is zero. This makes the introduction of more efficient wood stoves very difficult, because the investment is non-essential. In the case of other fuels some initial investment is essential. The relatively low cost of paraffin primus stoves has lead to the widespread use of this fuel compared to gas. The transition to gas is thus limited and slow. Where households do purchase gas stoves the level of investment that this entails, as well as the cost of electric stoves, tend to encourage the continued use of gas even after electrification (Viljoen, 1990:115). This retards the transition to complete reliance on electricity.

The order in which appliances are acquired also shows some trends which impact on energy use - particularly the quantity consumed. When paraffin becomes available and affordable, a stove is usually the first item needed and purchased, followed by lamps and in rare cases refrigerators. Gas is usually used for cooking, although gas lamps and gas refrigerators are available. Cecelski *et al.* (1979:26), referring to international experiences, note that when access to electricity is established, lights are usually the first appliances acquired followed by electric stoves, radios, fans and irons, and then refrigerators, hot water geysers and air conditioners. In South Africa television sets are also high on the list.

The initial costs of appliances that enable the use of wind or solar energy are generally beyond the means of most households. Their use is, therefore, almost entirely restricted to higher income groups. The transition to these energy sources is thus directly affected by the price of the appliances.

3.2.5 Scarcity/availability

Scarcity and availability may appear to describe opposite sides of the same coin. However, in this context scarcity is used to describe the gradual exhaustion of biomass fuels, while availability refers to the extent of access to commercial fuels, e.g. grid electrification.

The increasing scarcity of fuelwood in rural and peri-urban areas has given rise to at least three trends: firstly, fuelwood scarcity in very low income, usually remote rural regions inevitably results in the burning of other biomass resources as fuels. The use of dung and crop residues is common in South Africa and increases as fuelwood scarcity increases. This trend to substitute fuelwood with even lower grade biomass fuels can be described as reverse energy transition, but may also be seen as an intermediate stage before households start to use commercial fuels. Secondly, the scarcity of fuelwood has prompted energy planners to develop technologies intended to alleviate the problem. Solar cookers, hot boxes, improved wood stoves and biogas plants are examples, as are the planting of woodlots and the development of agroforestry. Without wanting to minimise the importance of these efforts, it unfortunately appears that "knowledge about energy-related technology greatly exceeds knowledge about the problems which the technology is meant to solve" (Barnett *et al.*, 1982:1). Consequently, adoption of some technologies has been slow and generally only of local importance. Still, the changes that have occurred represent a process of energy transition; either a shift towards more efficient and sustainable use of existing fuels, or a shift to completely new sources of energy such as solar power or biogas. The third, and predominant, trend resulting from fuelwood scarcity encompasses the commercialisation of fuelwood and the substitution of fuelwood with transitional energy sources, namely, coal, paraffin and gas. Both these changes are widespread in South Africa. Which of the transitional energy sources is adopted depends on, among other things, their relative availability. The predominance of coal in Gauteng and Mpumalanga may be ascribed to the fact that it is readily available there and, therefore, is cheaper than other fuels. Paraffin is available everywhere and so in areas where coal is expensive it tends to be the predominant fuel.

The distribution network for paraffin is large and pervasive and consists of both formal and informal traders. The nature of the fuel facilitates this. On the other hand, the gas distribution system is largely formal and restricted to urban centres due to the indivisibility of gas (Viljoen, 1990:118). As a result, gas is less important than paraffin or coal in the domestic energy transition process.

The availability of electricity is a *sine qua non* for the transition process to progress beyond transitional energy sources. The lack of grid extensions to townships and rural areas in South Africa has retarded the energy transition for many decades. Only recently have the government, Eskom and city councils begun to give this matter the attention it deserves.

3.2.6 Urbanisation

Various studies suggest that there is some correlation between urbanisation levels and patterns of domestic energy consumption. For instance, Viljoen (1990:43), after analysing data from 14 African countries, notes that "in countries with higher levels of urbanisation there is a shift away from woodfuel to paraffin and electricity." Such correlation, however, should come as no surprise. The important question is whether they should be ascribed to the urbanisation process itself or to the host of other changes that occur along with it. If a household moves from a rural area where fuelwood is abundant to an urban area where it is scarce, should the resulting change in that household's energy consumption pattern be ascribed to the move or to the increase in the scarcity of fuelwood that was experienced as a result of the move? Many other changes also occur with urbanisation - energy sources not available in rural areas are available in urban areas (to those who can afford them), access to free energy sources becomes restricted, people are exposed to modern lifestyles and advertising, employment opportunities and incomes are generally higher in urban areas, there is easier access to education, etc. It is evident from the other sections in this chapter that all these changes may affect the domestic energy transition process regardless of whether they occur in an urban or rural setting. However, many of them are almost integral to the urbanisation process or, stated differently, urbanisation is a necessary condition for their occurrence. It therefore seems reasonable to argue that urbanisation itself is a potential cause of the domestic energy transition process. There will, however, always be great difficulty in distinguishing its impact from those of all the other factors associated with it.

It should be noted that a distinction is made between an increase in the urban-rural ratio due to a higher rate of population growth in urban areas and due to migration from rural areas. In the former case, any changes in energy use patterns should be ascribed to increasing population pressure and not to the process of urbanisation. So Viljoen's (1990:43) finding that "when the rate of urban growth is high the per capita consumption of woodfuel is higher, while that of electricity is lower" may not point towards any causative relationship between urbanisation and the domestic energy transition process. Urbanisation should only be regarded as a cause of energy transition where households physically relocate from a rural to an urban area.

3.2.7 Type of dwelling

The type of dwelling affects energy use in at least two ways. Firstly, the quantity of energy required for space heating is affected by the design, the orientation, the materials used in construction and the size of the house. Secondly, the electricity grid is at present only being extended to residential areas that have been formally subdivided into plots, i.e. squatter camps are not being electrified (Opperman, Eskom: personal communication).

Siegfried's (1984) study of indigenous hut architecture in the former Transkei shows that traditional building practices optimise indoor temperatures. Despite outdoor temperature variations between 0 and 40 degrees , the temperatures inside these traditional dwellings remained within three degrees of the optimum of 18 degrees. This means that households who live in traditional dwellings are able to conserve energy sources that would otherwise have had to be used for space heating. By contrast most housing in resettlement areas and in peri-urban/informal areas utilise materials, designs and construction methods that are not conducive to energy conservation. Iron sheeting and plastic have poor insulation properties. Consequently such houses become excessively hot by day/summer and extremely cold by night/winter. Cold poses the greatest problem. These households have great difficulty keeping warm despite using significant amounts of energy for space-heating - most of the heat being lost through the roof and walls or simply through gaps resulting from poor construction. Even some low cost formal housing is so poorly designed that it requires more space heating than traditional housing. Section 7.2.2 discusses a number of energy conserving design features that can be incorporated during the construction of houses at minimal extra cost. The most important of these is the orientation of houses. All new houses should be oriented so as to utilise the passive heating effects of the sun. Failure to do so means a valuable opportunity to save energy is lost.

Middle and upper class housing is also often poorly designed from an energy conservation perspective. Large windows, open plan designs and excessive use of concrete, for instance, lead to rapid heat loss. Generally, though, this class of housing is better constructed and greater use is made of energy conserving/insulation materials. Certainly within the urban domestic energy transition the type/quality of housing a household has access to is an important determinant of its space heating requirements. Access to better housing, *ceteris paribus*, means a household needs to use less energy for space heating.

The size of the dwelling also has an impact on the amount of energy needed to keep it warm. Obviously the larger the house the more energy is needed. Middle and upper class housing is invariably more expansive than economy housing and so requires more energy for space warming. In this sector the effect of house size thus tend to counteract the beneficial effects of better design and construction noted above.

As noted above, the second way the type of dwelling affects the domestic energy transition process relates more to the tenure system of an area than to the type of housing. In order to plan the reticulation of electricity (and other services) property borders need to be clearly defined. This means that informal housing can be electrified so long as it is established on properly surveyed plots. Indeed there are many examples of where self-help housing on such plots have been supplied with electricity, e.g. Rhini near Grahamstown. It would seem that given the overwhelming demand for electrification the availability of such plots has become one of the determinants of whether households can progress from using paraffin, coal and gas to having access to electricity. Certainly in many squatter areas the lack of clearly defined property rights and properly surveyed sights is the major reason for these areas not having been able to take this step in the domestic energy transition process.

3.2.8 Attitudes/preferences

That attitudes and preferences can affect the progress of the domestic energy transition process is closely linked to the discussion of the picture and empathy effects in section 2.2. A positive attitude towards an energy source is the first step towards making the transition to using it. Attitudes are most often changed by exposure to the advantages of different patterns of energy use. The picture effect which operates within the domestic work sector in South Africa is important in this regard. People employed in modern households become familiar with the convenience of gas and electricity. It is then only a small step for them to desire the same services for themselves. The transition from simply desiring access to actually demanding it has been facilitated by the spread of empathy. Empathy enables people to imagine themselves enjoying greater access to the energy sources they see other people enjoying and also develop the freedom/will within themselves to demand that such access be granted to them as well.

In rural areas the more modern households are often those that use paraffin. Their example and the fact that paraffin is cleaner and more convenient than biomass fuels cause households to regard paraffin as preferable. When these preferences are acted upon, household energy consumption patterns change, i.e. by people exercising their preferences, the energy transition process is moved forward. Similarly, the process whereby the picture effect leads to changes in people's attitudes and then people act on their new preferences may be partly behind the increased use of gas in urban areas. The persistence of relatively high levels of gas use after electrification is probably also the result of households giving effect to their preferences; many households prefer gas to electricity for cooking because it is faster and easier to regulate.

There can be little doubt that the widespread demand for electrification is a reflection of people's preferences for this energy source above all others. This preference is rooted in the convenience and cleanliness of electricity, as well as its perceived economy. Even more important in determining people's preferences are the multitude of services and the quality of these services to which electricity (along with various appliances) give access.

Another area where attitudes and preferences play an important causal role in the domestic energy transition process is in the adoption of energy conservation measures. People's attitudes towards the environment as a whole and towards specific environmental problems are a major determinant of the extent to which they are prepared to implement conservation measures. In most instances households will only adopt energy conservation measures if the benefits are tangible and direct, i.e. either a lower energy bill or a cleaner, healthier home environment. Fortunately most energy conservation measures do deliver such benefits and the principal reason why they have not been adopted is that people are not aware of them. Information regarding these measures needs to be disseminated more widely. However, the success of energy conservation also requires a change of attitude; there needs to be greater appreciation of the impacts that human activities have on the environment and of the links between the environment and human welfare. As attitudes change in this direction, the domestic energy transition will be able to progress to the phase where energy conservation becomes the most important consideration.

3.2.9 Modernisation

In section 2.2 it was noted that modernisation is widely regarded as a type of social change that is progressive in its effect and that leads to improved levels of existence. Section 2.2 also discussed various theories of how modernisation occurs. This section focuses on the relationship between the broader process of modernisation and the process of energy transition.

Depending on one's focus, this relationship can be interpreted in various ways. On the one hand, the change in energy consumption patterns resulting from the energy transition process may be regarded as an integral part of the process of modernisation. In other words, the transition to more 'modern' energy sources is evidence of modernisation. Or taken a step further, the availability and use of energy sources such as gas and electricity promote the process of modernisation by enabling households to attain higher levels of energy service and, hence, a "new level of existence". On the other hand, the process of modernisation may be seen to facilitate or to cause changes in household energy consumption patterns, i.e. progressive households are likely to transform their energy consumption patterns in response to their improved (modernised) level of existence. This is in line with the principle of structural compatibility whereby society is seen as consisting of many parts combined into an integrated whole (see section 2.2). Thus, if any of the variables (parts of society) relevant to modernisation show some "progressive" change then the need for structural compatibility would induce an appropriate degree of change in the patterns of energy consumption so that the different parts of the whole remain in some kind of equilibrium. For instance, if a household moves into formal housing, it is likely to want and be able to get access to electricity. However, the roles could also be reversed: progressive change in the area of energy use would create a need for other areas of life to 'catch-up'. Trying to sort out which effects are operable or the direction of causation in different situations is very difficult.

Various studies discuss the relationship between modernisation and the domestic energy transition process. For instance, Viljoen (1990:91) uses a "modernisation index" in his description of the domestic energy transition process. However, it has already been noted in section 2.3.2 that there are limitations to his index: it includes variables, such as place of birth, that are only remotely relevant to the energy transition process, while ignoring others that are important variables of modernisation, e.g. education. Apart from this, the evidence he mentions is for the most part based on correlations between time urbanised and aspects of energy use such as expenditure on fuels and types of fuel consumed. It is found that time urbanised is strongly correlated with expenditure on the major fuels. Viljoen (1990:101) suggests this indicates "that as a population 'modernises' its expenditure on fuel will increase, whether or not income has increased." When he divides his survey sample into groups according to the predominant fuels used it is found that time urbanised increases across the groups in the following order: paraffin, mixed, gas and electricity. He argues that "this is an indication of a transition away from the use of paraffin and towards the use of electricity as modernisation proceeds" (Viljoen, 1990:106). The use of time urbanised as a proxy for modernisation has its problems since the relationship between the two is by no means clear. Some people may have lived in urban areas all their lives, but because they have been trapped in a cycle of poverty their pattern of energy use may not have modernised. By contrast, other people may migrate from rural areas where electricity is not available, but on their arrival in the city they may gain immediate access to housing that is electrified. In both cases time urbanised has little to do with the level of modernisation; instead, a host of other variables are relevant.

3.2.10 Other factors

In addition to the factors discussed in the previous sections, there are several other potential causes of the domestic energy transition process that need to be briefly mentioned.

Population pressure This factor may be regarded as a cause once removed: it is not the number of people *per se* that is a cause, but rather the effect that large numbers have on the supply of energy sources such as fuelwood. Where population pressure leads to the depletion of energy resources, households are forced to seek alternatives. The transition to using dung/crop wastes and paraffin in the second phase of the rural domestic energy transition can be ascribed largely to population pressure leading to the scarcity of fuelwood. Fuelwood is also not used in urban areas because the number of people in these areas means the demand outstrips supply many times over, consequently people have to rely on other energy sources.

Geographical location This factor is particularly relevant to the rural domestic energy transition. To start with, the availability of biomass fuels varies from region to region and so the pressure to start using commercial fuels varies as well. Secondly, climate differs from one area to another, which has a direct impact on households energy use patterns. Thirdly, households in remote rural areas are unlikely to gain access to grid electricity now or in the future, which means they are either going to have to continue relying on fuelwood and/or paraffin or develop stand alone electricity systems.

Political power Communities that are able to put pressure on government, municipalities or even Eskom are likely to gain access to electricity sooner than communities with less political clout. At present rural communities are at a disadvantage in this regard because of the difficulties associated with mobilising these communities in order to press their demands effectively.

Time It is not a cause of transition in its own right and yet the longer households have access to energy sources such as paraffin and electricity the more varied their pattern of use seems to become. This is especially so with regard to electricity where it takes households time to build up a stock of appliances. The passage of time may therefore be depicted as a necessary condition for the operation of other factors which do affect the domestic energy transition process.

3.3 Causes of the domestic energy transition process

This section looks at the operation of the above mentioned causes within the framework of the standard model described in section 2.3.3. The aim is to identify those causal factors that impact on the progress of the domestic energy transition process during each of its phases. Attention is given first to the rural energy transition, then to the factors affecting changes in energy use patterns that occur when households move from rural to and urban areas, then to the factors affecting the urban energy transition and, lastly, to some overall trends.

3.3.1 Causes of the rural energy transition

(i) *The first rural transition phase* The pattern of domestic energy consumption in rural subsistence areas shows little tendency to change under normal circumstances. This is because access to fuelwood is free, people prefer fuelwood to other biomass energy sources and households' cash incomes are so low that they are unable to afford paraffin and other commercial energy sources - where these energy sources are in fact available. The low level of household incomes also means that appliances such as wood stoves and primus stoves are not affordable.

Changes in any of the above factors would precipitate changes in patterns of domestic energy use. For example, if incomes increased households would be more likely to start using paraffin and the price of stoves would present less of an obstacle. A decline in the supply of fuelwood is, however, the principal cause of changes in energy consumption patterns in this phase of the energy transition.

(ii) *The second rural transition phase* Factors affecting energy use in this phase are mainly of a demographic or economic nature. An increase in population results in greater pressure being placed on the natural resource base of a region. The scarcity of fuelwood is a sign of this pressure. However, in most areas the loss of tree cover is largely a consequence of land being appropriated for uses other than growing trees, cultivation and housing being the most important of these alternative uses. Indeed the collection of fuelwood only contributes significantly to its own scarcity when instead of collection being restricted to dead wood, live trees are cut down. This usually only occurs when fuelwood is already very scarce.

The scarcity of fuelwood increases the real cost of this energy source in many ways: it has to be fetched from further afield; it is more time-consuming, arduous and hazardous to collect; and there is a decline in the quality of fuelwood available. A sure sign of fuelwood scarcity is that it becomes commercialised. Once this happens it is only a matter of time before paraffin becomes competitive. One of the prerequisites for this to happen is the existence of a comprehensive distribution network to 'bring paraffin to the people'. The share of paraffin in the total household energy budget will, thus, tend to increase as it becomes more readily available and as the supply becomes more reliable.

The level of household incomes is the most important economic factor affecting this phase of energy transition. If incomes are very low neither the initial outlay on paraffin stoves nor the ongoing cost of the paraffin is likely to be within households' means, but as incomes rise both appliances and fuel will become more affordable. Income levels are dependent both on the region's level of economic development and on the way it is integrated into the economies of more developed/urban regions. The higher the level of economic development and the closer the links with more developed areas, the higher incomes in the specific rural area are likely to be.

Modernisation, as a result of education and the factors mentioned in the above paragraph, also affects the rate and extent of the transition from fuelwood to paraffin: the need for night lighting, the desire to be more modern, and the greater cleanliness and convenience of paraffin all cause it to be preferred to fuelwood.

(iii) *The third rural transition phase* The most important factor affecting the energy transition process in this phase is probably the level of household income. Incomes affect not only the type of fuel consumed, but also the quantity of energy and the rate at which new fuels are adopted. For most households in this phase an increase in income would enable them to increase their fuel (paraffin) consumption, purchase a wider variety of appliances (lamps and refrigerators), and in some cases start to use gas for cooking. Households in the top income brackets will be able to link up with the electricity grid or, if the grid is not accessible, to invest in stand-alone electric generators. Once a household has access to electricity, irrespective of its source, it will start accumulating electric appliances.

The availability of alternate fuels, namely gas and electricity, is also relevant to the process of transition in this phase. A reliable and accessible gas distribution network will favour the adoption of this fuel, while access to the national electricity grid will enable households that can afford it to hook-up. A region's geographic location and level of economic development are important in determining the availability of gas and electricity. Areas close to major urban centres are more likely to have access to these fuel sources. The existence of a rural electrification programme may also hasten the transition to electricity in this phase. It is also likely, *ceteris paribus*, that politically important or powerful regions will obtain access to the electricity grid sooner than other regions.

Time is the last factor that is important in this third phase. The energy consumption pattern that establishes itself after the second phase of rural transition is likely to be fairly stable. However, with the passage of time households get used to using the new fuels, their expectations change or they become modernised and rural development gradually takes effect. As a result, patterns of energy consumption will gradually change and while the passage of time is not the direct cause, it is nevertheless a prerequisite for the other factors mentioned to take place.

3.3.2 Energy transition during urbanisation

In section 3.2.6 it was noted that though there is some correlation between levels of urbanisation and patterns of domestic energy consumption, the urbanisation process itself is only causally related to the energy transition in so far as its occurrence is a necessary condition for a host of other factors to take effect. In other words, the changes in energy use that occur when a household moves from a rural to an urban area are most likely precipitated by other changes that occur along with the move. The most obvious is a change in geographical location. The household may be moving to a new climate zone, to an area where coal is more abundant/scarce or to an area where fuelwood resources have been depleted. Each of these changes will necessitate adaptations to the household's pattern of energy use.

Relocation to an urban area also means moving to a new house. On the one hand this may lead to a fall in housing quality, since most new arrivals move into the informal housing sector. On the other hand a household may be fortunate to be able to move into formal housing. Either way, the household's pattern of energy use will have to adapt to the new home environment. It was noted above (section 3.2.7) that informal dwellings usually require more heating than traditional dwellings found in rural areas. Most households' levels of energy consumption will, therefore, tend to increase on arrival in urban areas.

One of the principal changes that may occur is that the urbanising household gets access to electricity. The likelihood of this happening is far greater if they move into formal housing or into an area where the plots have been properly surveyed for urban development. Urban areas are also being electrified far more rapidly than rural areas, which increases their chances of getting access to electricity.

The extent to which households are able to adapt to the new set of circumstances is largely dependent on their level of income. All energy sources in urban areas are commercialised, so the amount of energy a household can use will depend on what it can afford. Households will also need to purchase appliances in order to be able to use the new energy sources, especially if they get access to electricity. Newly urbanised households with no income will find it very difficult indeed, since free energy resources are exceptionally scarce, if not unobtainable, in urban areas. It should, however, be noted in this regard that urban income levels are usually higher than rural income levels, even for the poor.

Finally, a process of modernisation may accompany the process of urbanisation, which in turn would affect household energy consumption patterns. This is said with care given that there does not seem to be any direct link between time urbanised and modernisation (section 3.2.9). Nevertheless, when households move to urban areas they will inevitably be exposed to different value systems, technologies and opportunities. The extent to which they adopt and adapt will have an impact on their pattern of energy use. Where a household adopts a 'modernised' lifestyle its use of energy will obviously have to change to be compatible.

3.3.3 Causes of the urban energy transition

(i) *The first urban transition phase* The main factor affecting energy consumption patterns in the first urban energy transition phase is the scarcity of fuelwood. If fuelwood were freely available most households in this phase would show a preference for it because of cost factors. As it is, fuelwood is in short supply and therefore commercialised; in many areas its price is comparable to that of paraffin. The fact that paraffin is more portable and can be traded in small quantities makes it a good replacement for fuelwood. As a result extensive distribution networks for paraffin have been developed. The cost of a primus stove may make it difficult for very poor households to use this energy source, but for most urban households such stoves are not too expensive. Instead, households' level of income tends to restrict the amount of paraffin they can afford to consume.

(ii) *The second urban transition phase* Numerous factors affect the transition process in this phase, but their relative importance differ from household to household. As already indicated, rising incomes enable households to purchase the more expensive gas and gas appliances, as well as the minor fuels such as candles and batteries. The relative cost of gas to paraffin and the cost of gas appliances are also factors. The initial investment that is required to be able to use gas is substantially higher than it is for paraffin. This may be a serious obstacle in the transition towards greater reliance on gas and accounts for the persistence in paraffin use for a long time after gas has become available. Obviously a supply network for gas is essential for it to be adopted. Gas requires a far more formal supply network than paraffin. This means it is generally slower to develop than the paraffin network and tends to be concentrated in the older urban areas.

In this phase households tend to adopt gas because on the one hand it is more convenient than paraffin or coal, while on the other hand electricity is not available to them as yet. If electricity were to become widely available to households in the previous phase of the transition process it is possible that the role of gas in the process would be significantly reduced. Since access to electricity is often closely linked to access to formal housing, this factor is also an important determinant of the energy transition in this phase.

Lastly, modernisation (reflected in rising expectations, greater familiarity with different types of fuels, improved education, changing cooking and eating habits, greater awareness of cleanliness and the desire for more free time) also contributes to the energy transition in this phase.

(iii) *The third urban transition phase* The main factor affecting the transition process in this phase is the availability of electricity, which is almost entirely dependent on the process of electrification, i.e. the rate at which the national grid is extended to previously unconnected residential areas. Numerous factors determine how, where and when electrification is undertaken. There are economic and development considerations, as well as political factors. The political factors relate on the one hand to the government's relationship with particular communities and, on the other hand, to a community's capacity to make effective demands on public resources. On both counts urban areas fare better than rural areas.

The development considerations include matters such as the health and welfare advantages that accompany the electrification process, access to the mass media - particularly television - and the general modernising effect that seems to be associated with the use of electricity.

The economic considerations can be divided between those operating at the macro level and those affecting the micro level. The former relates to the costs, benefits and financing of extensions to the electricity grid and related infrastructure, while the latter relates to economic factors that households take into consideration before hooking up. These factors include the price of electricity relative to the price of gas or paraffin, the cost of wiring a house, the cost of the initial hook-up and the relative cost of gas appliances versus electric appliances. It has already been noted that in the case of stoves the high level of investment involved in the purchase of a gas stove and the cost of electric stoves will tend to encourage households to continue to use gas for cooking - and thus retard the rate of transition to electricity.

The access of households to formal housing is another important factor affecting the rate of the energy transition process in this third phase. Formal houses are likely to be electrified before the grid is extended to informal settlements, both because it is easier to create the infrastructure in formal areas and because the inhabitants of such areas are more likely to be able to afford the cost of installation and the user charges.

Lastly, preferences and modernisation also affect the transition process in this phase. Electricity is preferred to other fuels because it is clean, supplied on line (convenient) and has a wide range of uses (versatile). As a result households are inclined to make the change to this energy source if at all possible. This inclination is strengthened by changes in people's expectations, levels of education and the example effect of the urban milieu - all of which are aspects of modernisation.

(iv) *The fourth urban transition phase* As in the previous phase the rate of electrification is the most important factor affecting the rate of energy transition in this phase. At present Eskom is electrifying about 300 000 houses a year and intends to maintain this rate for at least the next five years (Opperman, 1994:2). By any standards this is an impressive achievement and means a very rapid transition from paraffin and gas to electricity is taking place. Indeed in some areas electrification is so rapid that access to suitably surveyed plots is becoming a constraint on the process and, therefore, also a constraint on the energy transition process. Households unable to gain access to such plots are also unable to get access to electricity.

Once households have access to electricity, the level of consumption is largely determined by economic factors such as income levels, the price of appliances and the cost of the electricity. The higher a household's income the less sensitive it is likely to be to the cost of electricity and the price of appliances and, consequently, the higher the level of energy consumption is likely to be. The length of time households have had access to electricity also seems to be correlated with the quantity consumed. However, again the passage of time is not a causal factor, but merely a necessary condition for households to accumulate appliances and develop energy intensive habits.

Finally, the energy transition in this fourth phase is affected by the extent of environmental socialisation, i.e. the degree to which people are positively disposed towards the environment and aware of the need and the means to conserve energy. The more sensitive people are to such issues and the greater the perceived benefits of any energy conservation measures the more likely people are to incorporate energy saving behaviour into their patterns of energy use. Where there are economic incentives or direct environmental benefits to be had people will be more inclined to change. In this regard the cost of alternative, energy saving appliances is an important determinant of the rate of transition to a less energy intensive pattern of behaviour.

3.3.4 Overall trends

All the causal factors discussed in section 3.2 affect the domestic energy transition process in all its different phases. However, the extent of each factor's affect will differ in each phase, some predominating during the early phases of transition, others later. The previous three sections drew attention to these changing impacts. There are, nevertheless, some broader trends that are worth emphasising.

During the entire rural energy transition the status of fuelwood supply is the most important causal factor. Where fuelwood is scarce, factors such as the availability of alternative energy sources, particularly paraffin, and the income to purchase them and their associated appliances are important. In all the phases of the urban energy transition the most important determinant is the availability of electricity or rather the rate of electrification. No other single factor is moving the energy transition process forward to the same extent, although it is possible that in some areas the lack of suitably surveyed plots may be operating as a constraint. Other important causal factors affecting energy transition in all the urban phase are income levels, the cost of energy sources and appliances and the impact of modernisation.

As regards the whole domestic energy transition process, the most important factors are those that relate to the availability of the different energy sources and the ability of households to purchase them, i.e. again the status of fuelwood supplies and paraffin distribution networks, the availability of electricity and, lastly, households' income earning opportunities.

CHAPTER 4

ENERGY SOURCES AND HOUSEHOLD WELFARE

This chapter seeks to identify trends in energy sources' contribution to household welfare at different stages in the domestic energy transition process. In order to do this it is necessary to collate, standardise and summarise data on energy consumption levels from various studies and to investigate how these patterns of energy use affect household welfare. The section also gives attention to the availability and versatility of different energy sources. Availability is crucial in determining what energy options are open to households, and versatility gives an indication of the number of tasks an energy source can perform and, hence, its potential for enhancing welfare. Other factors that affect the particular energy source's impact on household welfare are also listed. These lists complement the discussion in chapter 6, where the welfare implications of household energy consumption patterns are examined in far greater detail.

The main energy sources are treated separately in sections 4.1 to 4.6. Some pertinent points relating to the minor energy sources and to energy conservation are made in section 4.7. Section 4.8 wraps up by deriving total useful energy consumption levels and identifying trends in the characteristics of energy sources used at different stages of the domestic energy transition process. But before proceeding several of points need to be made regarding the calculation of nett energy and useful energy values, the different data sources and the format of the tables.

Calculating nett energy and useful energy values

The impact that the use of a particular energy source has on household welfare is determined by many factors; the most important is the quantity of *useful energy* households derive from it. This variable measures the amount of energy households actually use and derive benefit from. It is important to use this variable in assessing an energy source's contribution to welfare, rather than household nett energy consumption, since the energy-use efficiencies of different energy sources vary widely. To illustrate the difference, assume there are two households whose levels of nett energy consumption are equal, but the one uses fuelwood and the other gas. If their welfare position were assessed on the basis of this information they may appear equally well-off. However, the energy-use efficiency of gas is about five times that of fuelwood, i.e. the household using gas would be deriving nearly five times more useful energy and, hence, benefit than the household using fuelwood; consequently, their welfare would differ by a similar amount.

Nett energy consumption measures the total amount of energy 'delivered' to households and is calculated by multiplying the physical quantities of energy households consume by the energy source's calorific value in order to obtain equivalent energy values, which are expressed in gigajoules (GJ = 1000 MJ). Various calorific values are found in the literature. These are presented in the table 4.1, with those used in this study noted in the final column. Given the narrow range of values for each of the energy sources, it does not matter too much which are used. This study uses the values noted by Eberhard (1986).

Table 4.1: Calorific values of different energy sources

Energy source	Best (1979)	United Nations (1986)	Eberhard (1986)	Rivett-Carnac (1990)	Used here
fuelwood (15% moisture)	21-23 MJ/kg	-	17 MJ/kg	17 MJ/kg	17 MJ/kg
dung (40% moisture)	11.5-16.5 MJ/kg	-	12 MJ/kg	-	12 MJ/kg
coal	30 MJ/kg	-	27 MJ/kg	25 MJ/kg	27 MJ/kg
paraffin	38 MJ/l	43.2 MJ/l	37 MJ/l	36.7 MJ/l	37 MJ/l
gas	-	45.5 MJ/kg	49 MJ/kg	49.5 MJ/kg	49 MJ/kg
electricity	-	-	-	3.6 MJ/kwh	3.6 MJ/kwh

Note: 1 MJ = 0.001 GJ

Useful energy consumption is calculated by multiplying the nett energy consumption amounts by the energy-use efficiency values associated with each energy source. Table 4.2 presents energy-use efficiencies found in the literature. Again those used in this study appear in the final column.

Table 4.2: Energy-use efficiency of different energy sources

Energy source	Prosad *et al.* (1983)	Viljoen (1990)	Rivett-Carnac (1990)	Eberhard *et al.* (1991)	Used here
Fuelwood - open fire	-	-	13-25%	10%	13%
- stove	-	10%	11-30%	-	13%
Dung - open fire	-	-	-	10%	10%
Coal - brazier	-	-	-	15%	15%
- stove	-	20%	<16%	-	15%
Paraffin - stove	54-57%	50%	47-50%	50%	50%
- lamp	-	-	-	50%	50%
Gas - stove	55%	75%	60%	75%	60%
Electricity - stove	-	80%	55%	-	70%

Data sources

The data used in this section are taken from six different studies, namely:

Best (1979) - who studied the fuel consumption of three villages in Lesotho, Transkei and KwaZulu, visiting them both in summer and in winter. The sample sizes are comparatively small, but the fuel used was measured with some rigour.

Liengme (1983) - who studied the use of wood for both fuel and building in Gazankulu. Daily fuelwood consumption data are presented separately for each of the 14 households surveyed. The inclusion of the household sizes facilitated the conversion of this data to the format used here.

Eberhard (1986) - who studied household energy consumption in six rural areas and five peri-urban/urban areas across South Africa. This set of data is an invaluable source of information and the format of reporting is the same as that adopted here. The samples were sufficiently large to give reliable results.

Viljoen (1990)- who studied energy use in a number of peri-urban/urban areas in the Western Cape and one in the Transvaal. He divides the Cape data according to the characteristics of the areas surveyed (see Viljoen, 1990:38). This may affect the spread of the data between the samples. The data were reported in weekly consumption amounts which necessitated multiplying it up to get annual figures. The whole sample data also had to be changed from useful energy consumption levels to physical quantities. This was done using the energy-use efficiency and calorific values given in the study itself (see Viljoen, 1990:82-83). In addition, household data were converted into per capita data using the household sizes given in the study (see Viljoen, 1990:65). Though the samples were sufficiently large, it is felt that the calculations that were made to make this data comparable to data from the other sources reduces its reliability.

Rivett-Carnac (1990) - who studied energy consumption patterns of households in the Mariannhill district near Pietermaritzburg, Natal. The data are broken down into three "strata", i.e. peri-urban, township (non-electrified) and township (electrified), a format which is maintained here. Rivett-Carnac reports the fuelwood consumption data in terms of the physical amount of fuelwood households used, but the data for all the other energy sources are in terms of the monthly energy expenditure on the particular energy source. To make this data comparable the monthly expenditure values were divided by the fuel prices given in the study (see the notes to the tables) to obtain the physical quantities of energy used and then multiplied up to get annual figures. In addition, household data were converted into per capita data using the household sizes given in the study (see Rivett-Carnac, 1990:18). The size of the samples on which the data are based varied from 6 households that used fuelwood to 42 that used grid electricity. The reliability of the data therefore varies from one energy source to another. Again the calculations that were made to make the data comparable to that in other sources probably reduce its reliability as well.

Eberhard and Dickson (1991) - who studied energy consumption patterns in underdeveloped areas in Bophuthatswana. The format of data is the same as Eberhard (1986); consequently it is the same as that used here. The samples were also sufficiently large to give reliable results.

Format of the data tables

The data derived from the above mentioned studies have been divided into three transition stages, namely: the rural transition stage, the early urban transition stage and the late urban transition stage. These stages are not the same as the transition phases described in the standard model. They are a simplification in so far as the 'rural stage' incorporates all three phases of the standard model's rural transition process, while the 'early urban stage' and the 'late urban stage' incorporate the first two urban phases and the second two urban phases of the standard model's urban transition process respectively.

This format is adopted because the data from the six studies noted above were not originally collected with the seven phases of the standard model in mind and information that may have enabled the data to be divided into the various phases is lacking. The data is also presented in disaggregated form, i.e. the differences between households and, hence, the households' individual positions in the energy transition process have been hidden/lost. It would, therefore, be misleading to argue that a particular sample of households are all in the same phase of the energy transition process, while in reality there may be significant differences in their individual energy consumption patterns. The phases of the standard model are best suited to describe the energy use patterns of individual households rather than groups of them.

The three stages used in the tables in this section are obviously applicable to the data available since in most cases it is explicitly stated whether the samples are of rural, peri-urban or urban households. Only Viljoen's data posed categorisation problems since he divides it according to "new" and "old" formal and informal areas; the non-use of electricity in the sample was therefore used as indicative of the households being drawn from the early urban transition stage In all cases, if households in a sample used electricity and were located in an urban area, it was assumed they were in the late urban stage of transition.

The division of the data between these different stages is not completely satisfactory, but at least it still enables the discussion of the different welfare impacts of energy use to be related to the standard model of the energy transition process, even if only in the broadest terms.

4.1 Fuelwood

Table 4.3 presents household and per capita data on domestic fuelwood consumption. The physical amounts of fuelwood used are converted to nett energy consumption and useful energy consumption using the calorific value of 17 MJ/kg of fuelwood and an energy-use efficiency of 13%, as noted in tables 4.1 and 4.2 above.

Table 4.3: Useful energy derived from the domestic consumption of fuelwood per year only for households using fuelwood

Area	Source	Date	% H/H using energy source	Per Household			Per Capita		
				Physical amount (kg)	Nett energy consumption (GJ)	Useful energy consumption (GJ)	Physical amount (kg)	Nett energy consumption (GJ)	Useful energy consumption (GJ)
Rural Transition Stage									
Lesotho - Malefiloane	Best	1979	100	1745	29.67	3.86	335	5.70	0.74
Transkei - Jozanna's Nek	Best	1979	92	1898	32.27	4.19	302	5.13	0.67
KwaZulu - Mashunka	Best	1979	100	4824	82.01	10.66	1124	19.11	2.48
Gazankulu - Giyani area	Liengme	1983	100	5439	92.46	12.02	760	12.92	1.68
Ciskei - Lujiko	Eberhard	1986	100	3402	57.83	7.52	766	13.02	1.69
Transkei - Manzimahle	Eberhard	1986	100	2845	48.37	6.29	650	11.05	1.44
Transkei - Clarkebury	Eberhard	1986	100	2753	46.80	6.08	484	8.23	1.07
Transkei - Nkanga	Eberhard	1986	100	3777	64.21	8.35	498	8.47	1.10
Gazankulu - Cottondale	Eberhard	1986	100	3580	60.86	7.91	572	9.72	1.26
Lebowa - Mokumuru	Eberhard	1986	100	3358	57.09	7.42	655	11.14	1.45
Bophuthatswana - Bodibe	Eberhard[1]	1991	79	1812	30.80	4.00	300	5.10	0.66
Bophuthatswana - Madutle	Eberhard[1]	1991	95	2244	38.15	4.96	318	5.41	0.70
Bophuthatswana - Dinokana	Eberhard[1]	1991	100	2530	43.01	5.59	375	6.38	0.83
Bophuthatswana - Ganyesa	Eberhard[1]	1991	74	1798	30.57	3.97	402	6.83	0.89
Bophuthatswana - Deerward	Eberhard[1]	1991	90	3111	52.89	6.88	539	9.16	1.19
Bophuthatswana - Loopeng	Eberhard[1]	1991	100	3978	67.63	8.79	772	13.12	1.71
Bophuthatswana (rural average)	Eberhard[1]	1991	89	2642	44.91	5.84	454	7.72	1.00
Early Urban Transitional Stage									
Natal - Vulindlela	Eberhard	1986	98	5214	88.64	11.52	755	12.84	1.67
Qwa Qwa	Eberhard	1986	68	343	5.83	0.76	56	0.95	0.12
Bophuthatswana - Amatelang	Eberhard	1986	51	263	4.47	0.58	50	0.85	0.11
Cape - New Bethesda	Eberhard	1986	34	3042	51.71	6.72	648	11.02	1.43
Cape - Crossroads	Eberhard	1986	38	4019	68.32	8.88	566	9.62	1.25
Cape (old informal)	Viljoen	1990	2	-	-	-	-	-	-
Cape (new informal)	Viljoen	1990	3	-	-	-	-	-	-
Cape (average)	Viljoen	1990	1.7	-	-	-	-	-	-
Transvaal (new informal)	Viljoen	1990	85.1	758	12.89	1.68	181	3.08	0.40
Natal - Mariannhill (peri urban)	Rivett-Carnac	1990	31	2832	48.14	6.26	345	5.87	0.76
Natal - Mariannhill (t'ship non e.)	Rivett-Carnac	1990	15	2508	42.64	5.54	374	6.36	0.83
Bophuthatswana - Mmabatho	Eberhard[1]	1991	76	1075[2]	18.28	2.38	160	2.72	0.35
Late Urban Transition Stage									
Cape (old formal)	Viljoen	1990	0	0	0	0	0	0	0
Cape (new formal)	Viljoen	1990	2.5	-	-	-	-	-	-
Natal - Mariannhill (t'ship elec.)	Rivett-Carnac	1990	0	0	0	0	0	0	0

Note: 1. Eberhard (1991) is short for Eberhard and Dickson (1991).
2. Eberhard and Dickson (1991:47) report that households that collect their own fuelwood in Mmabatho use 930 kg, while those that purchase it use 1075 kg.

The most notable feature of the above table is the range in the quantity of useful energy and, hence, the varying amounts of welfare households derive from the use of fuelwood. Many households consume sufficient fuelwood to meet their basic need for energy, i.e. more than

1.5 3GJ of useful energy per capita; others do not. This is clearly shown in figure 4.1 below, which also gives some indication of the amount of useful energy derived from fuelwood by households at different stages in the domestic energy transition process.

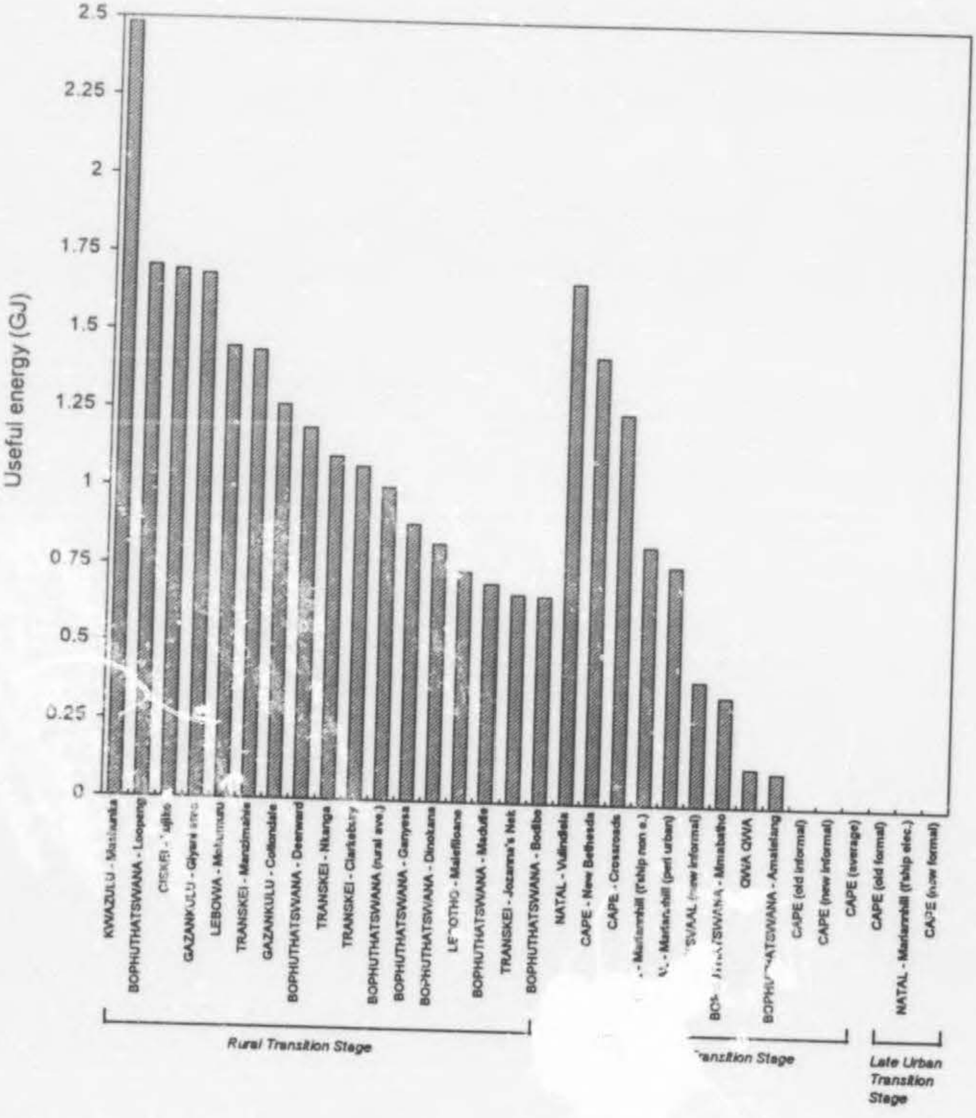


Figure 4.1: Per capita useful energy derived from fuelwood at different stages in the domestic energy transition only for households using fuelwood

The sequential ordering of the samples in each of the three transition stages is based on the useful energy derived from fuelwood and does not reflect greater or lesser progress in the energy transition process. From figure 4.1 it is evident that there is a decreasing trend in the amount of useful energy households derived from fuelwood in successive stages of the domestic energy transition. Consequently, fuelwood's contribution to household welfare may be expected to decrease in a similar manner.

The widespread availability of fuelwood in rural areas, as well as the fact that in these areas access to it is free, or at least does not require cash, is the principal reason why it occupies such an important position in the energy budgets of households in the rural transition stage. Indeed many households, particularly the poorest ones, rely on fuelwood almost entirely. Even where tree stocks have been depleted and fuelwood is scarce (see section 5.1.1), households will continue to rely mostly on fuelwood, but tend to use less energy overall. Only when shortages become acute or fuelwood is commercialised do households turn to other energy sources. In peri-urban and urban areas fuelwood is not often readily available, whereas other energy sources are. So from the early stages of the urban energy transition few households rely on fuelwood to the same extent as rural households do. Generally, only the poorest households use it to meet most of their energy needs; other households use varying quantities of fuelwood in combination with other energy sources. In the late stages of the urban energy transition fuelwood is used almost exclusively for luxury activities such as braais and hearth fires.

Fuelwood can be used to fulfil most of the basic needs for energy, and without the need for any appliances. Indeed the appliances available do not increase fuelwood's versatility, but tend to cause the tasks for which it is already used to be executed more efficiently. Fuelwood's main limitation is that it cannot be used for lighting, so households reliant on it usually use candles or paraffin for this purpose.

In addition to the above factors, fuelwood's impact on household welfare is affected by:

- the quality of fuelwood available to households - the scarcity of woods with desirable burning qualities affects household welfare negatively;
- the amount of time and effort, as well as risks, taken to gather fuelwood;
- the use of appliances such as stoves. Although these are not essential, they enhance the welfare households derive from fuelwood by increasing energy-use efficiency and smoke removal;
- the smoke - it is a health risk and reduces the amenity of the indoor environment (see section 5.1.1), though smoke may act as an insect-repellent and add a desirable taste to food;
- the open hearth provides a 'social centre';
- the low efficiency of fuelwood; and
- the fact that fuelwood is a renewable resource.

4.2 Dung/crop wastes

In table 4.4 household and per capita data on the domestic use of dung/crop wastes as an energy source are presented. Again, the relevant energy output and efficiency variables are used to generate data on nett energy and useful energy consumption.

Table 4.4: Useful energy derived from the domestic consumption of dung/crop wastes per year only for households using dung/crop wastes

Area	Source	Date	% H/H using energy source	Per Household			Per Capita		
				Physical amount (kg)	Nett energy consumption (GJ)	Useful energy consumption (GJ)	Physical amount (kg)	Nett energy consumption (GJ)	Useful energy consumption (GJ)
Rural Transition Stage									
Lesotho - Malefiloane	Best	1979	60	2919	35.03	3.50	561	6.73	0.67
Transkei - Jozanna's Nek	Best	1979	46	2159	25.91	2.59	343	4.12	0.41
KwaZulu - Mashunka	Best	1979	0	0	0	0	0	0	0
Gazankulu - Giyani area	Liengme	1983	0	0	0	0	0	0	0
Ciskei - Lujiko	Eberhard	1983	63	797	9.56	0.96	190	2.28	0.23
Transkei - Manzimahle	Eberhard	1986	50	921	11.05	1.11	187	2.24	0.22
Transkei - Clarkebury	Eberhard	1986	100	1312	15.74	1.57	231	2.77	0.28
Transkei - Nkanga	Eberhard	1986	100	1064	12.77	1.28	126	1.51	0.15
Gazankulu - Cottondale	Eberhard	1986	13	1777	21.32	2.13	229	2.75	0.27
Lebowa - Mokumuru	Eberhard	1986	97	565	6.78	0.68	112	1.34	0.13
Bophuthatswana - Bodibe	Eberhard[1]	1991	72	2002	24.02	2.40	777	9.32	0.93
Bophuthatswana - Madutle	Eberhard[1]	1991	63	1105	13.26	1.33	154	1.85	0.18
Bophuthatswana - Dinokana	Eberhard[1]	1991	25	572	6.86	0.69	91	1.09	0.11
Bophuthatswana - Ganyesa	Eberhard[1]	1991	10	-	-	-	-	-	-
Bophuthatswana - Deerward	Eberhard[1]	1991	57	2635	31.62	3.16	543	6.52	0.65
Bophuthatswana - Loopeng	Eberhard[1]	1991	31	3530	42.43	4.24	714	8.57	0.86
Bophuthatswana (rural average)	Eberhard[1]	1991	44	2244	26.93	2.69	546	6.55	0.66
Early Urban Transitional Stage									
Natal - Vulindlela	Eberhard	1986	20	-	-	-	-	-	-
Qwa Qwa	Eberhard	1986	66	-	-	-	-	-	-
Bophuthatswana - Amatelang	Eberhard	1986	10	-	-	-	-	-	-
Cape - New Bethesda	Eberhard	1986	16	-	-	-	-	-	-
Cape - Crossroads	Eberhard	1986	0	0	0	0	0	0	0
Cape (old informal)	Viljoen	1990	0	0	0	0	0	0	0
Cape (new informal)	Viljoen	1990	0	0	0	0	0	0	0
Cape (average)	Viljoen	1990	0	0	0	0	0	0	0
Transvaal (new informal)	Viljoen	1990	0	0	0	0	0	0	0
Natal - Mariannhill (peri urban)	Rivett-Carnac	1990	0	0	0	0	0	0	0
Natal - Mariannhill (t'ship non e.)	Rivett-Carnac	1990	0	0	0	0	0	0	0
Bophuthatswana - Mmabatho	Eberhard[1]	1991	18	-	-	-	-	-	-
Late Urban Transition Stage									
Cape (old formal)	Viljoen	1990	0	0	0	0	0	0	0
Cape (new formal)	Viljoen	1990	0	0	0	0	0	0	0
Natal - Mariannhill (t'ship elec.)	Rivett-Carnac	1990	0	0	0	0	0	0	0

Note: 1. Eberhard (1991) is short for Eberhard and Dickson (1991).

From the table it is evident that dung is widely used as an energy source in rural areas, particularly the former homeland areas. The amounts used are surprisingly large - some households may obtain as much as a fifth of their useful energy from this source.

Figure 4.2 shows how much useful energy households derive from dung/crop wastes at different stages in the domestic energy transition process. The notes on figure 4.1 's compilation apply equally to this figure.

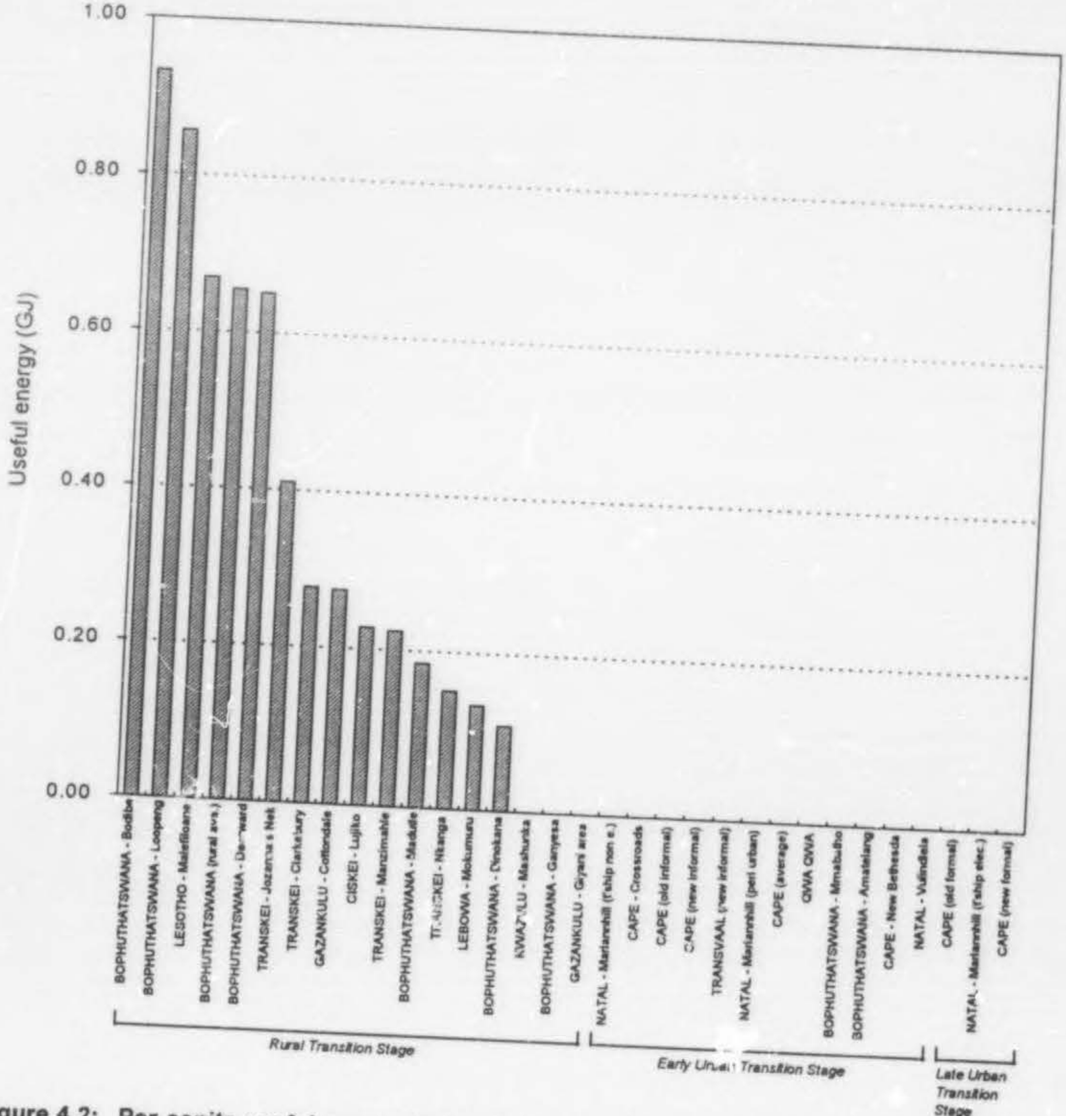


Figure 4.2: Per capita useful energy derived from dung/crop wastes at different stages in the domestic energy transition only for households using dung/crop wastes

Clearly dung/crop wastes are almost only used as an energy source in the rural energy transition. From the figure it is also evident that none of the households using this energy source derive sufficient energy from it to meet their basic energy needs. It may, therefore, be assumed that dung/crop wastes are used as a supplementary energy source by households experiencing shortages of fuelwood. Since paraffin is available in most areas, it may further be assumed that dung is consumed because it is a 'free' resource. As such it is a fuel of last resort for households that do not have access to other energy source or cannot afford them.

Dung/crop wastes are not very versatile energy sources, since they burn inefficiently. They are used, along with fuelwood, for cooking and heating water, but they generate too much smoke to be an acceptable source of energy for space warming.

Other factors affecting dung/crop wastes' impact on household welfare include:

- the acceptability of using dung/crop wastes as a source of energy;
- the inefficiency of dung as a source of energy;
- the opportunity costs of burning dung and crop wastes (see section 5.1.2);
- the time and effort expended to collect and prepare these fuels; and
- the smoke, which is a health risk and reduces the amenity of the home (section 5.1.2).

4.3 Paraffin

Table 4.5 presents data on domestic paraffin consumption gathered from various sources. As in the previous two sections, the nett energy and useful energy consumption of households is calculated using the relevant energy output and efficiency variables. The range in the quantity of useful energy that households derive from paraffin is broadly similar to that reported for fuelwood in table 4.3. However, in the case of paraffin the nett energy consumed is about five times less than when fuelwood is used. This illustrates the crucial importance of energy-use efficiency. Also notable is the lower bulk of paraffin versus fuelwood: to obtain 1000 MJ of useful energy would require just 54 litre of paraffin as opposed to 590 kg of fuelwood. Using paraffin, therefore, increases household welfare by decreasing the amount of effort required to bring energy to the place of use (*ceteris paribus*).

Table 4.5: Useful energy derived from the domestic consumption of paraffin per year only for households using paraffin

Area	Source	Date	% H/H using energy source	Per Household			Per Capita		
				Physical amount (l)	Nett energy consump-tion (GJ)	Useful energy consump-tion (GJ)	Physical amount (l)	Nett energy consump-tion (GJ)	Useful energy consump-tion (GJ)
Rural Transition Stage									
Lesotho - Malefiloane	Best	1979	100	66	2.44	1.22	12.7	0.47	0.23
Transkei - Jozanna's Nek	Best	1979	100	136	5.03	2.52	21.6	0.80	0.40
KwaZulu - Mashunka	Best	1979	78	32	1.18	0.59	7.4	0.27	0.14
Gazankulu - Giyani area	Liengme	1983	-	-	-	-	-	-	-
Ciskei - Lujiko	Eberhard	1986	100	130	4.81	2.41	28	1.04	0.52
Transkei - Manzimahle	Eberhard	1986	96	199	7.36	3.68	45	1.67	0.83
Transkei - Clarkebury	Eberhard	1986	98	142	5.25	2.63	24	0.89	0.44
Transkei - Nkanga	Eberhard	1986	100	96	3.55	1.78	10	0.37	0.19
Gazankulu - Cottondale	Eberhard	1986	85	196	7.25	3.63	28	1.04	0.52
Lebowa - Mokumuru	Eberhard	1986	97	54	2.00	1.00	10	0.37	0.19
Bophuthatswana - Bodibe	Eberhard[1]	1991	74	167	6.18	3.09	33	1.22	0.61
Bophuthatswana - Madutle	Eberhard[1]	1991	93	88	3.26	1.63	15	0.56	0.28
Bophuthatswana - Dinokana	Eberhard[1]	1991	100	138	5.11	2.55	19	0.70	0.35
Bophuthatswana - Ganyesa	Eberhard[1]	1991	83	217	8.03	4.01	50	1.85	0.93
Bophuthatswana - Deerward	Eberhard[1]	1991	98	260	9.62	4.81	46	1.70	0.85
Bophuthatswana - Loopeng	Eberhard[1]	1991	97	178	6.59	3.29	30	1.11	0.56
Bophuthatswana (rural average)	Eberhard[1]	1991	91	178	6.59	3.29	33	1.22	0.61
Early Urban Transitional Stage									
Natal - Vulindlela	Eberhard	1986	83	156	5.77	2.89	20.6	0.76	0.38
Qwa Qwa	Eberhard	1986	85	159	5.88	2.94	31.4	1.16	0.58
Bophuthatswana - Amatelang	Eberhard	1986	56	279	10.32	5.16	65.6	2.43	1.21
Cape - New Bethesda	Eberhard	1986	94	264	9.77	4.88	57.6	2.13	1.07
Cape - Crossroads	Eberhard	1986	100	679	25.12	12.56	95.7	3.54	1.77
Cape (old informal)	Viljoen	1990	100	445	16.47	8.23	83	3.07	1.54
Cape (new informal)	Viljoen	1990	100	294	10.88	5.44	81	3.00	1.50
Cape (average)	Viljoen	1990	92.2	362	13.39	6.70	66	2.44	1.22
Transvaal (new informal)	Viljoen	1990	94	203	7.51	3.76	49	1.81	0.91
Natal - Mariannhill (peri urban)	Rivett-Carnac	1990	95	289[3]	10.69	5.35	35	1.30	0.65
Natal - Mariannhill (t'ship non e.)	Rivett-Carnac	1990	77	283[3]	10.47	5.24	42	1.56	0.78
Bophuthatswana - Mmabatho	Eberhard[1]	1991	96	233[2]	3.62	4.31	34[2]	1.26	0.63
Late Urban Transition Stage									
Cape (old formal)	Viljoen	1990	77.2	350	12.95	6.48	51	1.89	0.94
Cape (new formal)	Viljoen	1990	97.5	331	12.25	6.12	63	2.33	1.17
Natal - Mariannhill (t'ship elec.)	Rivett-Carnac	1990	35	54[3]	2.00	1.00	8	0.30	0.15

Notes:
1. Eberhard (1991) is short for Eberhard and Dickson (1991).
2. These figures are based on total sample data because of uncertainty regarding data given in Eberhard and Dickson (1991:48) compared to that in Eberhard and Dickson (1991:46).
3. Rivett-Carnac (1990:19) reports that the paraffin price ranged between 65 cents and 70 cents per litre in the area he studied (April 1990). To convert the monthly paraffin expenditure data given by Rivett-Carnac (1990:19) to physical quantities a price of 67.5 cents per litre was assumed.

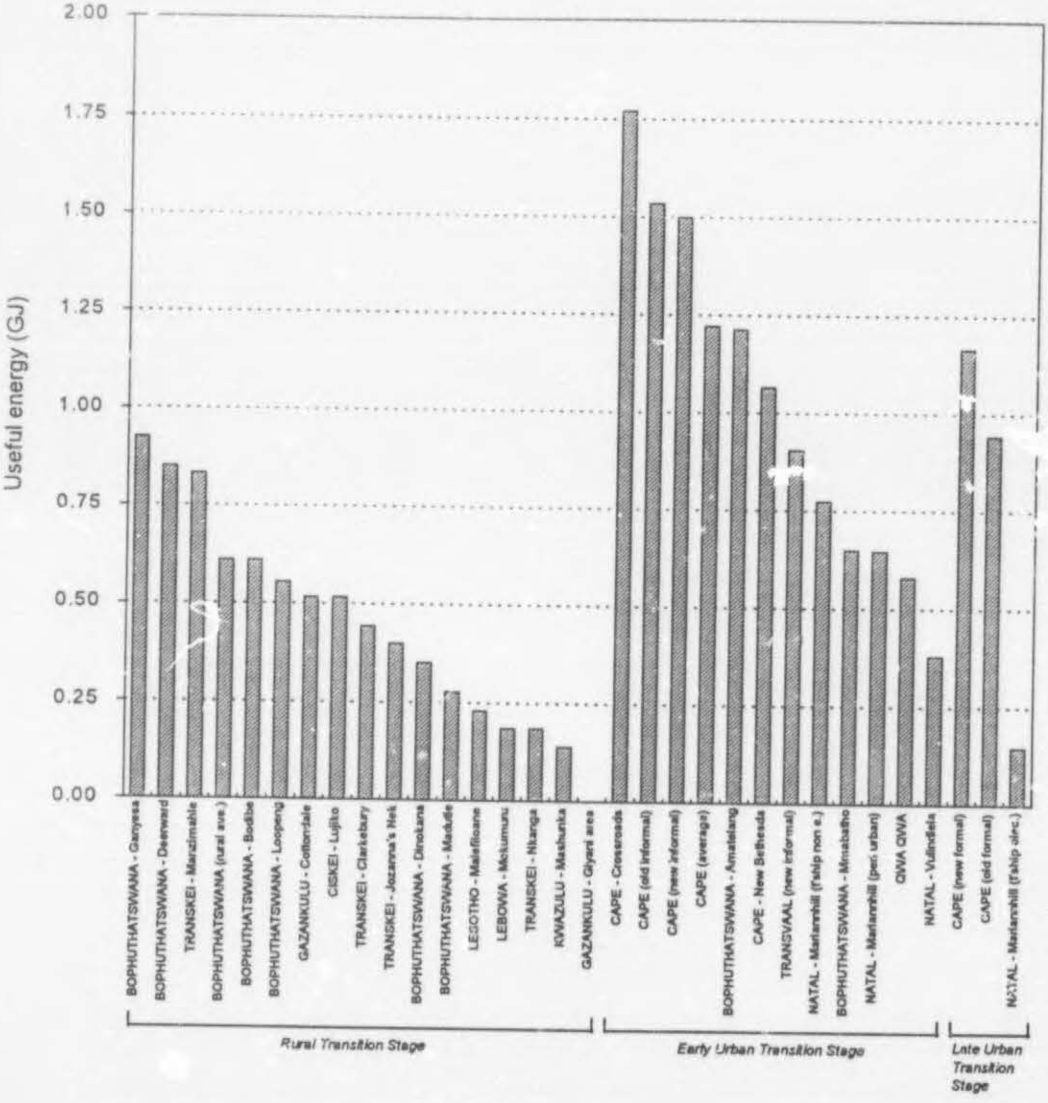


Figure 4.3: Per capita useful energy derived from paraffin at different stages in the domestic energy transition only for households using paraffin

Looking at the above figure it is clear that households in the rural transition and in the late urban transition stages only derive limited amounts of useful energy from paraffin. In rural areas income levels are limited, so households prefer to use fuelwood instead of paraffin because access to it is free. Paraffin is mostly used for lighting. Only rural households experiencing acute fuelwood shortages use more paraffin. In the late urban stages of the energy transition households have access to other energy sources, and only use paraffin as a back-up. By contrast, during the early stages of urban transition paraffin is an important source of useful energy, with many households consuming sufficient to meet their basic energy needs. More paraffin is used at this stage because fuelwood is scarce, electricity unavailable and the cost of paraffin appliances, which represent an 'access fee', is relatively low.

The distribution network for paraffin is widespread in both urban and rural areas. It is marketed from larger shops and through the informal sector where 'tuck shops' supply to households. Rivett-Carnac (1990:48) notes that paraffin's wide scale availability and the fact that it is relatively transportable and divisible are all reasons for its 'popularity'. The lack of access to acceptable alternatives such as gas and electricity is also an important consideration.

Paraffin is more versatile than fuelwood, but few households own all the appliances needed to realise this potential. Most households only own primus stoves and are, therefore, restricted to using paraffin for cooking and heating water. Paraffin is also commonly used for lighting - utilising either home-made or bought lamps. The main disadvantage of paraffin is that to use it for space heating and refrigeration requires appliances that are generally too expensive and use too much fuel for most household budgets.

In addition to the above factors, paraffin's impact on household welfare is affected by:

- the 'access fee' of purchasing paraffin appliances, particularly a primus stove;
- the price of paraffin and the percentage of income spent on this energy source;
- the convenience, health and amenity benefits of using paraffin instead of fuelwood or coal; and
- the possibility of children poisoning themselves by imbibing paraffin and the risk of serious burns and explosions.

4.4 Coal

Data on the domestic consumption of coal are presented in table 4.6. The form[illegible]e as that used in the previous sections.

Table 4.6: Useful energy derived from the domestic consumption of coal per year only for households using coal

Area	Source	Date	% H/H using energy source	Per Household: Physical amount (kg)	Per Household: Nett energy consump-tion (GJ)	Per Household: Useful energy consump-tion (GJ)	Per Capita: Physical amount (kg)	Per Capita: Nett energy consump-tion (GJ)	Per Capita: Useful energy consump-tion (GJ)
Rural Transition Stage									
Lesotho - Malefiloane	Best	1979	-	-	-	-	-	-	-
Transkei - [illegible]anna's Nek	Best	1979	-	-	-	-	-	-	-
KwaZulu - Mashunka	Best	1979	-	-	-	-	-	-	-
Gazankulu - Giyani area	Liengme	1983	-	-	-	-	-	-	-
Ciskei - Lujiko	Eberhard	1986	0	0	0	0	0	0	0
Transkei - Manzimahle	Eberhard	1986	6	392	10.58	1.59	88	2.38	0.36
Transkei - Clarkebury	Eberhard	1986	16	1148	31.00	4.65	191	5.16	0.77
Transkei - Nkanga	Eherhard	1986	0	0	0	0	0	0	0
Gazankulu - Cottondale	Eberhard	1986	38	1477	39.88	5.98	220	5.94	0.89
Lebowa - Mokumuru	Eberhard	1986	10	179	4.83	0.72	40	1.06	0.16
Bophuthatswana - Bodibe	Eberhard[1]	1991	58	630	17.01	2.55	104	2.81	0.42
Bophuthatswana - Madutle	Eberhard[1]	1991	2	960	25.92	3.89	128	3.46	0.52
Bophuthatswana - Dinokana	Eberhard[1]	1991	25	702	18.95	2.84	86	2.32	0.35
Bophuthatswana - Ganyesa	Eberhard[1]	1991	7	1014	27.38	4.11	164	4.43	0.66
Bophuthatswana - Deerward	Eberhard[1]	1991	8	1068	28.84	4.33	160	4.32	0.65
Bophuthatswana - Loopeng	Eberhard[1]	1991	9	840	22.68	3.40	117	3.16	0.47
Bophuthatswana (rural average)	Eberhard[1]	1991	12	775	20.93	3.14	112	3.02	0.45
Early Urban Transitional Stage									
Natal - Vulindlela	Eberhard	1986	3	1189	32.10	4.82	169	4.56	0.68
Qwa Qwa	Eberhard	1986	96	1734	46.82	7.02	322	8.69	1.30
Bophuthatswana - Amatelang	Eberhard	1986	92	1081	29.19	4.38	211	5.70	0.85
Cape - New Bethesda	Eberhard	1986	31	903	24.38	3.66	172	4.64	0.70
Cape - Crossroads	Eberhard	1986	45	3451	93.16	13.98	486	13.12	1.97
Cape (old informal)	Viljoen	1990	0	0	0	0	0	0	0
Cape (new informal)	Viljoen	1990	0	0	0	0	0	0	0
Cape (average)	Viljoen	1990	0	0	0	0	0	0	0
Transvaal (new informal)	Viljoen	1990	86.6	2115	57.11	8.57	506	13.66	2.05
Natal - Mariannhill (peri urban)	Rivett-Carnac	1990	13.6	1340[2]	36.18	5.43	163[2]	4.41	0.66
Natal - Mariannhill (t'ship non e.)	Rivett-Carnac	1990	9.4	1250[2]	33.7[illegible]	5.06	187[2]	5.04	0.76
Bophuthatswana - Mmabatho	Eberhard[1]	1991	42	975	26.33	3.95	146	3.94	0.59
Late Urban Transition Stage									
Cape (old formal)	Viljoen	1990	0	0	0	0	0	0	0
Cape (new formal)	Viljoen	1990	0	0	0	0	0	0	0
Natal - Mariannhill (t'ship elec.)	Rivett-Carnac	1990	0	0	0	0	0	0	0

Notes:
1. Eberhard (1991) is short for Eberhard and Dickson (1991).
2. Rivett-Carnac (1990:19) reports that price of coal ranged from 20 cents to 26.25 cents per kilogram in the area he studied (April 1990). To convert the monthly coal expenditure data given by Rivett-Carnac (1990:20-21) to physical quantities a price of 24 cents per kilogram was assumed.

From the above table it is evident that domestic coal consumption is confined almost entirely to areas close to South Africa's coalfields, namely KwaZulu-Natal, Gauteng and Mpumalanga. Secondly, households that do use coal tend to consume it in large quantities, i.e. there is not the range in coal use that was noted in the case of fuelwood and paraffin. Thirdly, coal is a bulky fuel. This is illustrated by extending the example introduced in the previous section: to obtain 1000 MJ of useful energy from coal would require 185 kg, which is less than the 590 kg for fuelwood, but still three times the 54 litre for paraffin. Note also that that households using coal were a minority in most survey samples. Coal use is, therefore, probably more limited than indicated in the table.

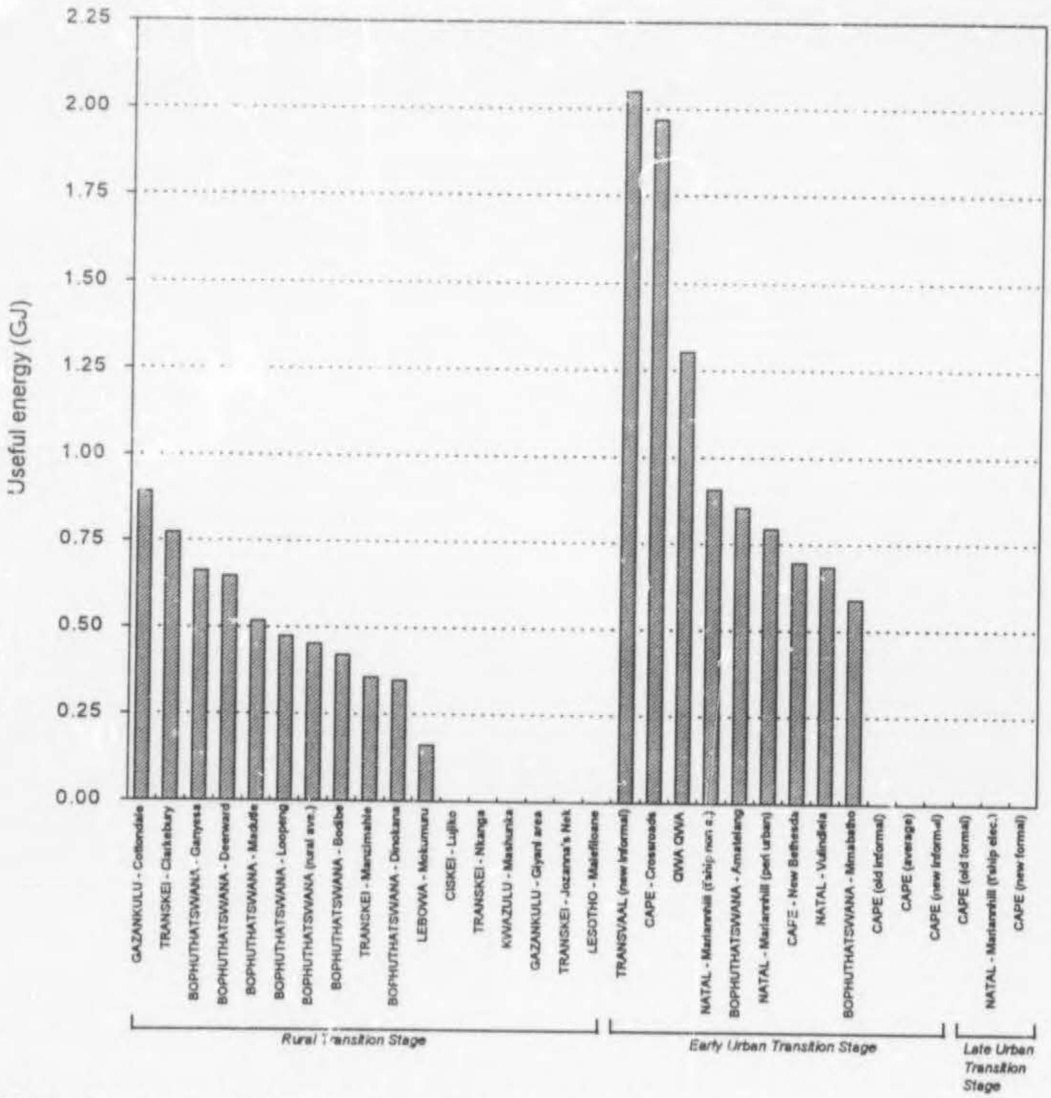


Figure 4.4: Per capita useful energy derived from coal at different stages in the domestic energy transition only for households using coal

In the rural transition domestic coal use is obviously limited. In the early urban transition those households that do use coal are usually in the minority and are confined to coal producing regions. In the late urban transition few households use coal once they have access to electricity, although as noted in section 7.1.3(b) the proportion may still be substantial in some areas; in Soweto 22% of newly electrified households still have coal stoves (Heyl, 1988).

The cost of coal due to high transportation costs confines its use to areas in and around coalfields and the main urban centres. The weight of coal means transportation costs are high, which inhibits distribution and, hence, use in the rural transition and in the early stages of urban transition. In the late urban transition stages convenience, cleanliness and the availability of other energy sources seem to be more important determinants of coal use than the availability of the fuel itself.

Coal is as versatile as fuelwood, except that it does not burn as readily in an open fire. As with wood appliances, coal appliances - in most cases coal stoves - also only enhance energy-use efficiency, but not versatility. Coal's main limitation is also that it cannot be used for lighting.

Other factors affecting coal's impact on household welfare include:

- the quality of coal households use;
- the physical characteristics of coal - it is heavy, dirty and difficult to light;
- the use of coal stoves. They enhance household welfare by increasing energy-use efficiency and smoke removal;
- the smoke - as noted in section 5.1.4 and 7.1.3(b) it reduces household welfare by affecting people's health and reducing the amenity of the home environment;
- the greater energy: weight ratio of coal, to that of fuelwood; and
- the price of coal and the percentage of income spent on this energy source.

4.5 Gas

Data on the domestic consumption of gas are presented below.

Table 4.7: Useful energy derived from the domestic consumption of gas per year only for households using gas

Area	Source	Date	% H/H using energy source	Per Household			Per Capita		
				Physical amount (kg)	Nett energy consump-tion (GJ)	Useful energy consump-tion (GJ)	Physical amount (kg)	Nett energy consump-tion (GJ)	Useful energy consump-tion (GJ)
Rural Transition Stage									
Lesotho - Malefiloane	Best	1979	-	-	-	-	-	-	-
Transkei - Jozanna's Nek	Best	1979	-	-	-	-	-	-	-
KwaZulu - Mashunka	Best	1979	-	-	-	-	-	-	-
Gazankulu - Giyani area	Liengme	1983	-	-	-	-	-	-	-
Ciskei - Lujiko	Eberhard	1986	0	0	0	0	0	0	0
Transkei - Manzimahle	Eberhard	1986	4	48	2.35	1.41	11.7	0.57	0.34
Transkei - Clarkebury	Eberhard	1986	9	130	6.37	3.82	17.9	0.88	0.53
Transkei - Nkanga	Eberhard	1986	9	59	2.89	1.73	3.3	0.16	0.10
Gazankulu - Cottondale	Eberhard	1986	8	129	6.32	3.79	19.5	0.96	0.57
Lebowa - Mokumuru	Eberhard	1986	0	0	0	0	0	0	0
Bophuthatswana - Bodibe	Eberhard[1]	1991	0	0	0	0	0	0	0
Bophuthatswana - Madutle	Eberhard[1]	1991	0	0	0	0	0	0	0
Bophuthatswana - Dinokana	Eberhard[1]	1991	0	0	0	0	0	0	0
Bophuthatswana - Ganyesa	Eberhard[1]	1991	19	118	5.78	3.47	28	1.37	0.82
Bophuthatswana - Deerward	Eberhard[1]	1991	28	115	5.64	3.38	18	0.88	0.53
Bophuthatswana - Loopeng	Eberhard[1]	1991	12	510	24.99	14.99	70	3.43	2.06
Bophuthatswana (rural average)	Eberhard[1]	1991	12	162	7.94	4.76	31	1.52	0.91
Early Urban Transitional Stage									
Natal - Vulindlela	Eberhard	1986	5	100	4.90	2.94	11.9	0.58	0.35
Qwa Qwa	Eberhard	1986	9	152	7.45	4.47	21.6	1.06	0.64
Bophuthatswana - Amatelang	Eberhard	1986	10	73	3.58	2.15	17.1	0.84	0.50
Cape - New Bethesda	Eberhard	1986	9	49	2.40	1.44	42.2	2.07	1.24
Cape - Crossroads	Eberhard	1986	4	396	19.40	11.64	48.7	2.39	1.43
Cape (old informal)	Viljoen	1990	24.5	361	17.69	10.61	67.6	3.31	1.99
Cape (new informal)	Viljoen	1990	17.6	362	17.74	10.64	99.8	4.89	2.93
Cape (average)	Viljoen	1990	31.7	495	24.26	14.55	90.5	4.43	2.66
Transvaal (new informal)	Viljoen	1990	23.9	217	10.63	6.38	52	2.55	1.53
Natal - Mariannhill (peri urban)	Rivett-Carnac	1990	35	198[2]	9.70	5.82	24.1	1.18	0.71
Natal - Mariannhill (t'ship non e.)	Rivett-Carnac	1990	39	177[2]	8.67	5.20	26.4	1.29	0.78
Bophuthatswana - Mmabatho	Eberhard[1]	1991	15	-	-	-	-	-	-
Late Urban Transition Stage									
Cape (old formal)	Viljoen	1990	31.6	531	26.02	15.61	77	3.77	2.26
Cape (new formal)	Viljoen	1990	55	575	28.18	16.91	109.2	5.35	3.21
Natal - Mariannhill (t'ship elec.)	Rivett-Carnac	1990	48	63[2]	3.33	2.00	10.2	0.5[illegible]	0.30

Note
1. Eberhard (1991) is short for Eberhard and Dickson (1991).
2. Rivett-Carnac reports that the price of gas ranged from R1.44 to R1.76 per kilogram in the area he studied (April 1990). To convert the gas expenditure data reported by Rivett-Carnac (1990: 20-22) to physical quantities a price of R1.60 per kilogram was assumed.

From table 4.7 it is evident that gas consumption is more concentrated in coastal areas, particularly the Cape. This may be partly due to the proximity of the main distributors and partly due to the remoteness of the coalfields. Also evident is the fact that households using gas tend to derive larger amounts of useful energy from it than households generally derive from any other energy source, except electricity.

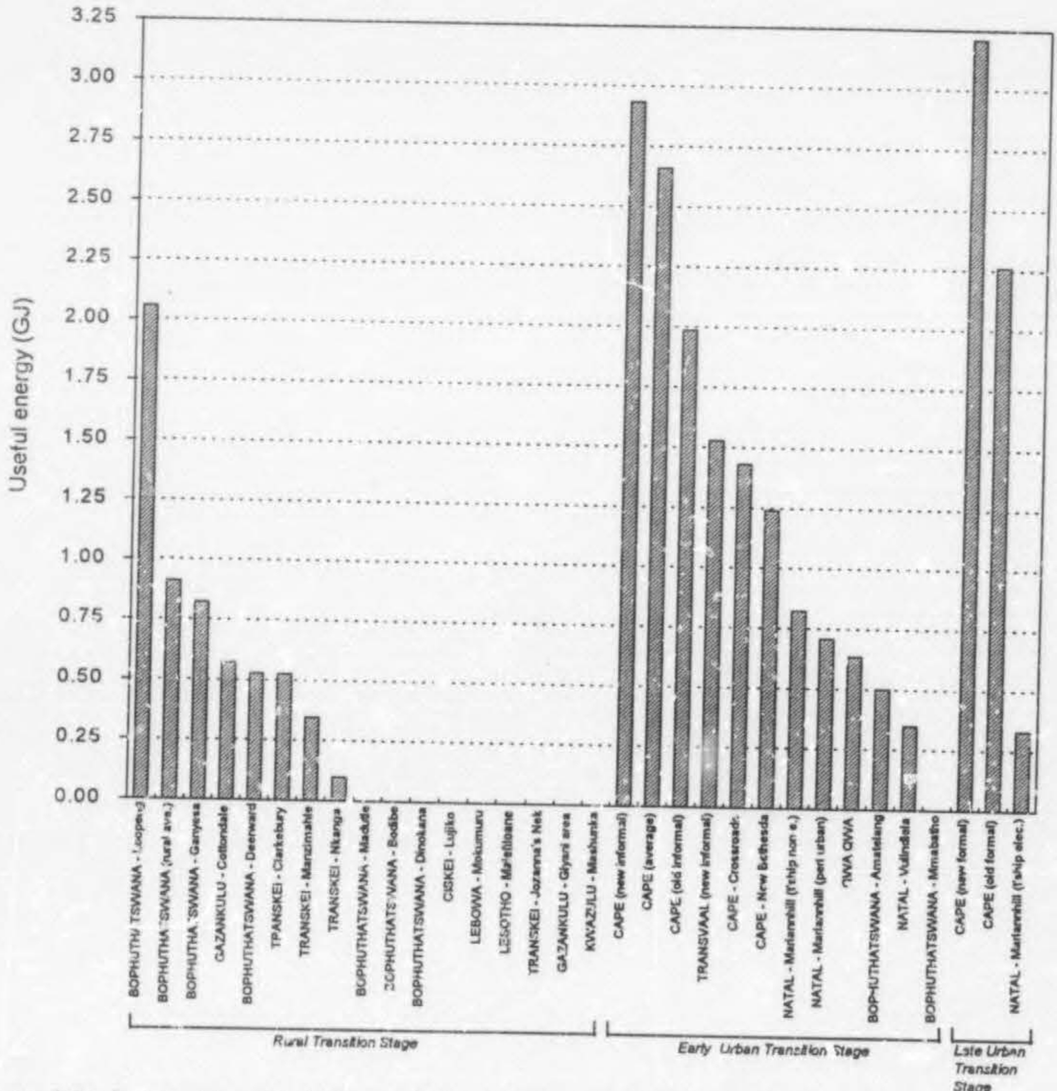


Figure 4.5: Per capita useful energy derived from gas at different stages in the domestic energy transition only for households using gas

Figure 4.5 shows clearly that gas consumption in rural areas is limited. By contrast, in the late stages of the urban transition gas becomes an important source of energy for those households that use it, which is between a third and half the households in the survey samples. Very noticeable is the fact that households using gas derived far more useful energy from it than households using paraffin. Whether this is because gas is more convenient and therefore lends itself to being consumed or because households using gas generally have higher incomes and therefore spend more on energy is uncertain. Also evident is that households continue to use gas in the late stages of the urban transition. Among the reasons for this is the convenience of gas and the level of investment in gas stoves.

The availability of gas is an important determinant of use, more so than is the case with fuelwood or paraffin. The gas distribution network tends to be restricted to urban centres and more especially the formal retailing sector, since shops selling gas require a licence to do so. Other constraints in the distribution network include the fact that deliveries from distributors to retailers are unreliable, the problem of transporting gas cylinders to and from home, the reluctance of taxi owners to transport gas cylinders, and the fact that many retailers only exchange cylinders and do not refill them (Rivett-Carnac, 1990:48).

Gas is potentially as versatile as paraffin when used in the appropriate appliances. However, most gas is used in stoves, since other gas appliances such as heaters, water geysers, lamps and refrigerators tend to be expensive.

Other factors affecting gas's impact on household welfare include:

- its convenience, cleanliness and efficiency compared to all the energy sources discussed thus far;
- the risk posed by accidental leaks and explosions;
- the price and percentage of income spent on gas; and
- the inconvenience of transporting gas cylinders.

4.6 Electricity

Only grid electricity is considered here; other sources of electricity are referred to in section 4.7. Data on the domestic consumption of electricity and on the useful energy derived from electricity at different stages in the domestic energy transition process are presented in table 4.8.

Table 4.8: Useful energy derived from the domestic consumption of electricity per year only for households using electricity

Area	Source	Date	% H/H using energy source	Per Household			Per Capita		
				Physical amount (kwh)	Nett energy consump-tion (GJ)	Useful energy consump-tion (GJ)	Physical amount (kwh)	Nett energy consump-tion (GJ)	Useful energy consump-tion (GJ)
Cape (old formal)	Viljoen	1990	49	6167	22.20	15.54	895	3.22	2.26
Cape (new formal)	Viljoen	1990	10	6406	23.06	16.14	1225	4.41	3.09
Cape (average)	Viljoen	1990	17.8	6197	22.31	15.62	1131	4.07	2.85
Natal - Mariannhill (t'ship elec)	Rivett-Carnac	1990	29	4020	14.47	10.13	600	2.16	1.51
Bophuthatswana - Mmabatho	Eberhard[1]	1991	4	-	-	-	-	-	-

Notes:
1. Eberhard (1991) is short for Eberhard and Dickson (1991).
2. Households in the rural and early stages of the urban energy transition processes seldom have access to electricity.
3. If a service charge of R2.20/mth is taken into account then these figures become Cape (old informal) - 5047 kwh; Cape (new informal) - 5286 kwh; and Cape (average) - 5078 kwh (Viljoen, 1990:80 and 86).

Households in the rural and early urban energy transition stages do not have access to electricity. Indeed, in the preceding tables electricity consumption is the distinguishing feature of the late urban transition stage. It is also evident that most households with access to electricity tend to consume more useful energy than households reliant on other energy sources. Not only do they consume sufficient to meet their basic energy needs, but also enough to meet many other needs and wants. In addition, the quality of energy service that electricity makes possible is superior to that supplied by other energy sources. For both these reasons households with electricity tend to enjoy a higher level of welfare than those without it.

Availability is more crucial in the case of electricity than for any other energy source due to the fact that it is supplied via a national grid. Access to this grid is a *sine qua non* to enjoying the benefits of electricity, but is only possible if the grid has been extended to the area. In the past, the grid electrification process was biased towards linking white communities. As a result access to electricity is characterised by racial inequality. Recent efforts by Eskom have begun to address this problem. More and more urban black households are being connected each year. In rural areas grid electricity is unlikely to become widely available within the next twenty years, and, even if it were, it is doubtful that many rural households would be able to afford it.

Electricity is the most versatile of the energy sources available to households. The variety of appliances that can be used with electricity is enormous. They enable households to use electricity for their basic energy needs, to simplify or facilitate other household activities, and for other energy services such as lighting, refrigeration and home entertainment. As a result electricity's potential for enhancing household welfare is significant.

In addition to the above factors, the impact of grid electricity on household welfare is affected by:

- the means of supply - it eliminates the time and effort that is required to bring each of the other energy sources to the home;
- the convenience of electricity - it has merely to be switched on;
- the fact that it is the cleanest energy source from the household point of view, so health risks associated with its use are very low (section 5.1.7);
- the cost of access to the grid;
- the tariff structure and price of electricity and the percentage of income spent on this energy source;
- the price of appliances; and
- the status value of having access to electricity.

4.7 Other energy sources

In addition to the above mentioned energy sources, a number of other energy sources are used in the domestic sector, namely candles, wet-cell batteries, dry-cell batteries and solar energy. The potential welfare impacts of biogas, as well as of energy conservation, are also discussed below. In most cases the amount of useful energy derived from these sources is small and yet they make a relatively important contribution to household welfare because of the nature of the services they provide. Table 4.9 presents data on the domestic consumption of candles, of dry-cell batteries and on recharges of wet-cell batteries.

Table 4.9: Domestic consumption of candles, dry-cell batteries and recharges of wet-cell batteries per household using these energy sources

Area	Source	Date	Per Household			Per Capita		
			Candles (no)	Dry-cells (R)	Wet-cells (rech.)	Candles (no)	Dry-cells (R)	Wet-cells (rech.)
Rural Transition Stage								
Lesotho - Malefiloane	Best	1979	-	-	-	-	-	-
Transkei - Jozanna's Nek	Best	1979	-	-	-	-	-	-
KwaZulu - Mashunka	Best	1979	-	-	-	-	-	-
Gazankulu - Giyani area	Liengme	1983	-	-	-	-	-	-
Ciskei - Lujiko	Eberhard	1986	68	-	-	12	-	-
Transkei - Manzimahle	Eberhard	1986	201	-	-	41	-	-
Transkei - Clarkebury	Eberhard	1986	225	-	-	40	-	-
Transkei - Nkanga	Eberhard	1986	197	-	-	22	-	-
Gazankulu - Cottondale	Eberhard	1986	358	-	-	49	-	-
Lebowa - Mokumuru	Eberhard	1986	273	-	-	52	-	-
Bophuthatswana - Bodibe	Eberhard[1]	1991	290	-	-	48	-	-
Bophuthatswana - Madutie	Eberhard[1]	1991	245	-	-	33	-	-
Bophuthatswana - Dinokana	Eberhard[1]	1991	284	-	-	35	-	-
Bophuthatswana - Ganyesa	Eberhard[1]	1991	376	-	-	61	-	-
Bophuthatswana - Deerward	Eberhard[1]	1991	348	-	-	52	-	-
Bophuthatswana - Loopeng	Eberhard[1]	1991	319	-	-	45	-	-
Bophuthatswana (rural average)	Eberhard[1]	1991	315	-	-	46	-	-
Early Urban Transitional Stage								
Natal - Vulindlela	Eberhard	1986	451	35.0[2]	-	66	5.0	-
Qwa Qwa	Eberhard	1986	314	14.0[2]	-	58	2.6	-
Bophuthatswana - Amatelang	Eberhard	1986	341	2.0[2]	-	71	0.4	-
Cape - New Bethesda	Eberhard	1986	250	17.0[2]	-	60	4.1	-
Cape - Crossroads	Eberhard	1986	504	59.0[2]	-	71	8.3	-
Cape (old informal)	Viljoen	1990	307	31.7	91	57	5.9	17.0
Cape (new informal)	Viljoen	1990	380	51.5	114	105	14.2	31.6
Cape (average)	Viljoen	1990	458	46.8	104	84	8.5	18.9
Transvaal (new informal)	Viljoen	1990	456	119.6	78	109	28.6	18.7
Natal - Mariannhill (peri urban)	Rivett-Carnac	1990	433	139.3	55	53	17.0	6.7
Natal - Mariannhill (t'ship non e.)	Rivett-Carnac	1990	387	134.9	38	58	20.1	5.7
Bophuthatswana - Mmabatho	Eberhard[1]	1991	-	-	-	-	-	-
Late Urban Transition Stage								
Cape (old formal)	Viljoen	1990	593	56.7	127	86	8.2	18.4
Cape (new formal)	Viljoen	1990	645	62.4	116	123	11.9	22.2
Natal - Mariannhill (t'ship elec.)	Rivett-Carnac	1990	96	103.3	34	14	15.4	5.0

Notes: 1. Eberhard (1991) is short for Eberhard and Dickson (1991).
2. Based on whole sample data.

(a) *Candles* These are probably the most widely used energy source. In KwaZulu-Natal, Rivett-Carnac (1990:19) reports that candles are used in 91% of non-electrified homes and 73% of electrified homes. In the Cape Town area the incidence of use ranges between 17.5 and 55.1%, while in an informal area in the former Transvaal it is 97% (Viljoen, 1990:77). From table 4.9, it is also evident that the range in the per capita consumption is large. In both the rural and early urban stages of energy transition households use significant numbers of candles, primarily because electric lighting is unavailable. In the late urban transition the consumption of candles declines appreciably. They are only used as a back-up light source or as a luxury for special occasions. Candle's impact on household welfare is also affected by their price (candles are a relatively expensive source of light), the poor quality light they provide and the fire hazard associated with their use.

(b) *Dry-cell batteries* The use of dry-cell batteries for radios and hifi's is common in non electrified homes. Other uses include torches and appliances like shavers. From the above table it would appear that households in the early urban transition use greater quantities of dry-cell batteries than households in the rural transition, although the pattern is by no means clear. Households with access to grid electricity use far fewer batteries. This energy source contributes to household welfare primarily in the area of home entertainment and in providing occasional or emergency lighting. The extent of these benefits is tempered by the price of batteries and their limited versatility.

(c) *Wet-cell batteries* These batteries are widely used in the early stages of the urban transition to power audio-visual appliances. Once households have access to grid electricity, use of this energy source declines. Use of these batteries also seems to some extent dependent on access to recharging facilities. The time and effort it requires to recharge, the cost of the batteries and of each recharge and the hazard of handling these batteries all reduce the impact this energy source has on household welfare.

(d) *Solar energy* Solar energy makes an important contribution to household welfare by its passive heating effect on the home environment. However, the purposeful use of this energy source with appliances such as solar water heaters or solar cookers, or to produce electricity with photovoltaics, is very limited. The use of solar water heaters is largely restricted to wealthier households in the late urban transition, as well as some farms where the labourers' cottages are provided with them. Solar water heaters have the potential to enhance household welfare significantly by ensuring a more or less consistent supply of hot water, particularly during the rural and early urban energy transition, when households do not have access to electricity and water geysers. However, the cost and financing restrictions need to be overcome before this means of utilising solar energy becomes viable for poorer households.

Solar cookers are another means of harnessing solar energy for domestic purposes. Advocates of this simple technology claim it has great potential to enhance household welfare by reducing the quantity of fuel - in most cases fuelwood - used for cooking and heating water. However, efforts to disseminate the technology have failed almost completely because the problems experienced with its use seem to outweigh the benefits. These problems include the restriction to cooking a single pot at midday, constant need to track the sun, no ancillary space heating benefits and the loss of social function of the fire. The cost of these devices is also a factor (Eberhard, 1986:20).

Photovoltaics could enhance the welfare of non-electrified households by supplying them with low power electrical services such as lighting and television. The scope is particularly great in rural areas that are unlikely to obtain access to the electricity grid for a long time. At present most photovoltaic systems in use supply energy to remote white farmsteads. For photovoltaics to realise their full welfare enhancing potential their price will have to fall significantly.

(e) *Biogas* Biogas is extensively used by households in India and China, where it makes an important contribution to household welfare. Factors affecting the extent of this contribution include savings on other energy sources, the fact that it is a clean, efficient fuel, the cost of a biodigestor and the time and effort required to operate it. A safe means of processing sewerage is an important secondary benefit. The obstacles to utilising biogas are also mentioned in section 7.2.4.

(f) *Energy conservation* In section 7.2 it is noted that the aim of energy conservation is to increase the efficiency with which present energy services are delivered, and to curtail certain excessive uses of energy. Both these sets of measures tend to increase household welfare by reducing the nett demand for energy and, hence, the expenditure on energy sources. The initial cost of some conservation measures or the need to change certain ingrained habits will tend to temper the welfare gains. Overall the potential welfare gains from energy conservation seem to be fairly evenly spread across the domestic energy transition process.

4.8 Summary and trends

In order to facilitate comparisons between the use of the different energy sources this section summarises some of the data on domestic energy use noted in this chapter and identifies overall trends. Table 4.10, on the following page, presents a summary of the information on the percentage of households in each of the samples that use the different energy sources.

From table 4.10 it is evident that during the rural transition stage both fuelwood and paraffin are very widely used. Few households, if any, only rely on fuelwood for their energy needs. Of greater concern is the high proportion of households in these samples that use dung. This suggests that many households in South Africa's rural areas are suffering from energy shortages, forcing them to adopt coping strategies such as the use of dung.

Table 4.10: Percentage of households using energy source

Area	Source	Date	Wood	Dung	Paraffin	Coal	Gas	Electricity	Candles	Batteries Dry-cell	Batteries Wet-cell
Rural Transition Stage											
Lesotho - Malefiloane	Best	1979	100	60	100	-	-	0	-	-	-
Transkei - Jozanna's Nek	Best	1979	92	46	100	-	-	0	-	-	-
KwaZulu - Mashunka	Best	1979	100	0	78	-	-	0	-	-	-
Gazankulu - Giyani area	Liengme	1983	100	-	-	-	-	0	-	-	-
Ciskei - Lujiko	Eberhard	1986	100	63[2]	100	0	0	0	45	69	0
Transkei - Manzimahle	Eberhard	1986	100	50[2]	96	6	4	0	58	29	2
Transkei - Clarkebury	Eberhard	1986	100	100[2]	98	16	9	0	98	40	4
Transkei - Nkanga	Eberhard	1986	100	100[2]	100	0	9	0	91	36	3
Gazankulu - Cottondale	Eberhard	1986	100	13[2]	85	38	8	0	85	73	6
Lebowa - Mokumuru	Eberhard	1986	100	97[2]	97	10	0	0	63	83	0
Bophuthatswana - Bodibe	Eberhard[1]	1991	79	72	74	58	0	0	100	61	-
Bophuthatswana - Madutle	Eberhard[1]	1991	95	63	93	2	0	0	74	35	-
Bophuthatswana - Dinokana	Eberhard[1]	1991	100	25	100	25	0	0	92	0	-
Bophuthatswana - Ganyesa	Eberhard[1]	1991	74	10	83	7	19	0	87	50	-
Bophuthatswana - Deerward	Eberhard[1]	1991	90	57	98	8	28	0	100	33	-
Bophuthatswana - Loopeng	Eberhard[1]	1991	100	31	97	9	12	0	91	16	-
Bophuthatswana (rural average)	Eberhard[1]	1991	89	44	91	12	12	0	90	32	-
Early Urban Transition Stage											
Natal - Vulindlela	Eberhard	1986	98	20	83	3	5	0	96	85	9
Qwa Qwa	Eberhard	1986	68	66	85	98	9	0	96	32	6
Bophuthatswana - Ama[illegible]ung	Eberhard	1986	51	10	56	62	10	0	64	8	13
Cape - New Bethesda	Eberhard	1986	84	16	94	31	9	0	88	66	9
Cape - Crossroads	Eberhard	1986	38	0	100	45	4	0	52	31	18
Cape (old informal)	Viljoen	1990	2	0	100	0	24.5	0	55	78	22
Cape (new informal)	Viljoen	1990	3	0	100	0	17.6	0	30	38	18
Cape (average)	Viljoen	1990	1.7	0	92.2	0	31.7	17.8	38	50	23
Transvaal (new informal)	Viljoen	1990	85.1	0	94	86.6	23.9	0	97	58	12
Natal - Mariannhill (peri urban)	Rivett-Carnac	1990	31	0	95	13.6	35	0[3]	91	72	40
Natal - Mariannhill (t'ship non e.)	Rivett-Carnac	1990	15	0	77	9.4	39	0[3]	91	91	40
Bophuthatswana - Mmabatho	Eberhard[1]	1991	76	18	96	42	15	4	87	38	9
Late Urban Transition Stage											
Cape (old formal)	Viljoen	1990	0	0	77.2	0	31.6	49.1	18	30	16
Cape (new formal)	Viljoen	1990	2.5	0	97.5	0	55	10	50	55	38
Natal - Mariannhill (t'ship elec.)	Rivett-Carnac	1990	0	0	35	0	48	100[3]	73	15	2

Notes:
1. Eberhard (1991) is short for Eberhard and Dickson (1991).
2. These percentages may also be Lujiko - 66%; Manzimahle- 73%, Clarkebury - 100%, Nkanga - 100%, Cottondale - 23% and Mokumuru - 100%. Compare Eberhard (1986:28) to Eberhard (1986:45).
3. Rivett-Carnac (1991:20) reports that 29% of the households in the entire Mariannhill sample have access to electricity.

In the early urban transition stages paraffin is the most widely used source of energy and, as might be expected, the use of coal and gas show significant regional differences. The range of samples in the late urban transition stage is too limited to be truly representative. Nevertheless, it is interesting to note that many households use a mix of energy sources even after they gain access to electricity.

Of the minor energy sources both candles and dry-cell batteries are extensively used which indicates that there is a significant demand for lighting and radio services. The levels of wet-cell battery use in the early urban transition stages point in the same direction.

The percentages in table 4.10 only indicate whether a household uses the energy source, but gives no indication of the extent of use. This information is found in tables 4.3 to 4.9 where the levels of useful energy consumption that households derive from particular energy sources are noted. These tables give an accurate indication of the contribution energy sources make to the welfare of households actually using them. However, when it comes to calculating total useful energy consumption, the total sample data presented in tables 4.11 and 4.12 must be used. The results of multiplying the figures in these tables by the associated energy output and energy-use efficiency values are presented in tables 4.13 and 4.14, and 4.15 and 4.16 respectively.

Table 4.11: Mean annual domestic energy consumption per household in total samples

Area	Source	Date	Wood (kg)	Dung (kg)	Paraffin (l)	Coal (kg)	Gas (kg)	Electricity (kwh)	Candles (no)
Rural Transition Stage									
Lesutho - Malefiloane	Best	1979	1500	1350	26.4	-	-	0	-
Transkei - Jozanna's Nek	Best	1979	1705	633	64	-	-	0	-
KwaZulu - Mashunka	Best	1979	4824	0	24	-	-	0	-
Gazankulu - Giyani area	Liengme	1983	5439	-	-	-	-	-	-
Ciskei - Lujiko	Eberhard	1986	3402	504	130	0	0	0	31
Transkei - Manzimahle	Eberhard	1986	2845	460	191	25	2	0	117
Transkei - Clarkebury	Eberhard	1986	2753	1312	139	179	12	0	220
Transkei - Nkanga	Eberhard	1986	3777	1064	84	0	5	0	180
Gazankulu - Cottondale	Eberhard	1986	3580	222	167	554	11	0	305
Lebowa - Mokumuru	Eberhard	1986	2920	545	52	18	0	0	174
Bophuthatswana - Bodibe	Eberhard[1]	1991	1386	1441	124	365	0	0	290
Bophuthatswana - Madutle	Eberhard[1]	1991	2124	696	82	19	0	0	181
Bophuthatswana - Dinokana	Eberhard[1]	1991	2479	143	138	176	0	0	261
Bophuthatswana - Ganyesa	Eberhard[1]	1991	1223	-	180	71	23	0	327
Bophuthatswana - Deerward	Eberhard[1]	1991	2792	1976	255	85	24	0	348
Bophuthatswana - Loopeng	Eberhard[1]	1991	3978	1096	173	76	31	0	290
Bophuthatswana (rural average)	Eberhard[1]	1991	2351	987	162	100	16	0	284
Early Urban Transitional Stage									
Natal - Vulindlela	Eberhard	1986	5213	?	129	32	5	0	438
Qwa Qwa	Eberhard	1986	343	?	135	1661	13	0	301
Bophuthatswana - Amatelang	Eberhard	1986	263	?	157	998	7	0	266
Cape - New Bethesda	Eberhard	1986	3042	?	248	282	5	0	219
Cape - Crossroads	Eberhard	1986	1527	0	679	1553	14	0	262
Cape (old informal)	Viljoen	1990	-	0	445	0	89	0	166
Cape (new informal)	Viljoen	1990	-	0	294	0	64	0	120
Cape (average)	Viljoen	1990	-	0	334	0	160	1376	172
Transvaal (new informal)	Viljoen	1990	758	0	191	2215	52	0	437
Natal - Mariannhill (peri urban)	Rivett-Carnac	1990	-	-	-	-	-	-	-
Natal - Mariannhill (t'ship non e.)	Rivett-Carnac	1990	-	-	-	-	-	-	-
Bophuthatswana - Mmabatho	Eberhard[1]	1991	908	-	233	400	20	-	267
Late Urban Transition Stage									
Cape (old formal)	Viljoen	1990	0	0	270	0	167	3784	104
Cape (new formal)	Viljoen	1990	-	0	323	0	315	802	322
Natal - Mariannhill (t'ship elec.)	Rivett-Carnac	1990	-	-	-	-	-	-	-

Notes: 1. Eberhard (1991) is short for Eberhard and Dickson (1991)

Table 4.12: Mean annual domestic energy consumption per capita in total samples

Area	Source	Date	Wood (kg)	Dung (kg)	Paraffin (l)	Coal (kg)	Gas (kg)	Electricity (kwh)	Candles (no)
Rural Transitional Stage									
Lesotho - Malefiloane	Best	1979	288	260	5.1	-	-	0	-
Transkei - Jozanna's Nek	Best	1979	271	80	10.2	-	-	0	-
KwaZulu - Mashunka	Best	1979	1124	0	5.7	-	-	0	-
Gazankulu - Giyani area	Liengme	1983	760	-	-	-	-	-	-
Ciskei - Lujiko	Eberhard	1986	766	120	28	0	0	0	5
Transkei - Manzimahle	Eberhard	1986	650	94	43	5.5	0.5	0	24
Transkei - Clarkebury	Eberhard	1986	484	231	23	29.7	1.6	0	39
Transkei - Nkanga	Eberhard	1986	498	126	10	0	0.3	0	20
Gazankulu - Cottondale	Eberhard	1986	572	28	24	82.5	1.6	0	42
Lebowa- Mokumuru	Eberhard	1986	655	108	10	4	0	0	33
Bophuthatswana - Bodibe	Eberhard[1]	1991	237	560	24	60	0	0	48
Bophuthatswana - Madutie	Eberhard[1]	1991	302	97	14	3	0	0	24
Bophuthatswana - Dinokana	Eberhard[1]	1991	375	23	19	22	0	0	32
Bophuthatswana - Ganyesa	Eberhard[1]	1991	297	-	42	12	4	0	51
Bophuthatswana - Deerward	Eberhard[1]	1991	485	407	45	13	4	0	52
Bophuthatswana - Loopeng	Eberhard[1]	1991	772	221	29	11	3.6	0	41
Bophuthatswana (rural average)	Eberhard[1]	1991	404	240	29	14	2.9	0	40
Early Urban Transition Stage									
Natal - Vulindlela	Eberhard	1986	742	-	17	5	0.5	0	62
Qwa Qwa	Eberhard	1986	39	-	27	308	1.8	0	56
Bophuthatswana - Amatelang	Eberhard	1986	26	-	37	195	1.8	0	45
Cape - New Bethesda	Eberhard	1986	648	-	54	54	3.9	0	53
Cape - Crossroads	Eberhard	1986	213	0	96	217	1.7	0	37
Cape (old informal)	Viljoen	1990	73	0	53	0	16.7	0	31
Cape (new informal)	Viljoen	1990	211	0	81	0	17.7	0	33
Cape (average)	Viljoen	1990	52	0	61	0	29.1	251	31
Transvaal (new informal)	Viljoen	1990	156	0	46	405	12.4	0	104
Natal - Mariannhill (peri urban)	Rivett-Carnac	1990	-	-	-	-	-	-	-
Natal - Mariannhill (t'ship non e.)	Rivett-Carnac	1990	-	-	-	-	-	-	-
Bophuthatswana - Mmabatho	Eberhard[1]	1991	134	-	34	59	3	-	39
Late Urban Transition Stage									
Cape (old formal)	Viljoen	1990	0	0	39	0	24.3	549	15
Cape (new formal)	Viljoen	1990	31	0	62	0	60.4	153	62
Natal - Mariannhill (t'ship elec.)	Rivett-Carnac	1990	-	-	-	-	-	-	-

Notes: 1. Eberhard (1991) is short for Eberhard and Dickson (1991).

Table 4.13: Domestic nett energy consumption per household per year in total samples

Area	Source	Date	Wood (GJ)	Dung (GJ)	Paraffin (GJ)	Coal (GJ)	Gas (GJ)	Electricity (GJ)	Total (GJ)
Rural Transition Stage									
Lesotho - Malefiloane	Best	1979	25.50	16.20	0.98	-	-	0	42.68
Transkei - Jozanna's Nek	Best	1979	28.99	7.60	2.37	-	-	0	38.96
KwaZulu - Mashunka	Best	1979	82.01	-	0.89	-	-	0	82.90
Gazankulu - Giyani area	Liengme	1983	92.46	-	-	-	-	0	92.46
Ciskei - Lujiko	Eberhard	1986	57.83	6.05	4.81	0	0	0	68.69
Transkei - Manzimahle	Eberhard	1986	48.37	5.52	7.07	0.68	0.10	0	61.73
Transkei - Clarkebury	Eberhard	1986	46.80	15.74	5.14	4.83	0.59	0	73.11
Transkei - Nkanga	Eberhard	1986	64.21	12.77	3.11	0	0.25	0	80.33
Gazankulu - Cottondale	Eberhard	1986	60.86	2.66	6.18	14.96	0.54	0	85.20
Lobowa - Mokumuru	Eberhard	1986	49.64	6.54	1.92	0.49	0	0	[illegible]
Bophuthatswana - Bodibe	Eberhard[1]	1991	23.56	17.29	4.59	[illegible]	0	0	55.30
Bophuthatswana - Madutle	Eberhard[1]	1991	36.11	8.35	3.03	0.51	0	0	48.01
Bophuthatswana - Dinokana	Eberhard[1]	1991	42.14	1.72	5.11	[illegible]	0	0	53.72
Bophuthatswana - Ganyesa	Eberhard[1]	1991	20.79	-	6.66	[illegible]	1.13	0	30.50
Bophuthatswana - Deerward	Eberhard[1]	1991	47.46	23.71	9.44	[illegible]	1.18	0	84.08
Bophuthatswana - Loopeng	Eberhard[1]	1991	67.63	13.15	6.40	[illegible]	1.52	0	90.75
Bophuthatswana (rural average)	Eberhard[1]	1991	39.97	11.84	5.99	[illegible]	0.78	0	61.29
Early Urban Transitional Stage									
Natal - Vulindlela	Eberhard	1986	88.62	-	4.77	0.86	0.25	0	94.50
Qwa Qwa	Eberhard	1986	5.83	-	5.00	44.85	0.64	0	56.31
Bophuthatswana - Amatelang	Eberhard	1986	4.47	-	5.81	26.95	0.34	0	37.57
Cape -New Bethesda	Eberhard	1986	51.71	-	9.18	7.61	0.25	0	68.75
Cape - Crossroads	Eberhard	1986	25.96	0	25.12	41.93	0.69	0	93.70
Cape (old informal)	Viljoen	1990	-	0	16.47	0	4.36	0	20.83
Cape (new informal)	Viljoen	1990	-	0	10.88	0	3.14	0	14.01
Cape (average)	Viljoen	1990	-	0	12.36	0	7.84	4.95	25.15
Transvaal (new informal)	Viljoen	1990	12.89	0	7.07	59.81	2.55	0	82.31
Natal - Mariannhill (peri urban)	Rivett-Carnac	1990	-	-	-	-	-	-	-
Natal - Mariannhill (t'ship non e.)	Rivett-Carnac	1990	-	-	-	-	-	-	-
Bophuthatswana - Mmabatho	Eberhard[1]	1991	15.44	-	8.62	10.80	0.98	0	35.84
Late Urban Transition Stage									
Cape (old formal)	Viljoen	1990	0	0	9.99	0	8.18	13.62	31.79
Cape (new formal)	Viljoen	1990	-	0	11.95	0	15.44	2.89	30.28
Natal - Mariannhill (t'ship elec.)	Rivett-Carnac	1990	-	-	-	-	-	-	-

Note: 1. Eberhard (1991) is short for Eberhard and Dickson (1991).

Table 4.14: Domestic nett energy consumption per capita per year in total samples

Area	Source	Date	Wood (GJ)	Dung (GJ)	Paraffin (GJ)	Coal (GJ)	Gas (GJ)	Electricity (GJ)	Total (GJ)
Rural Transition Stage									
Lesotho - Malefiloane	Best	1979	4.90	3.12	0.19	-	-	0	8.21
Transkei - Jozanna's Nek	Best	1979	4.61	0.96	0.38	-	-	0	5.95
KwaZulu - Mashunka	Best	1979	19.11	0	0.21	-	-	0	19.32
Gazankulu - Giyani area	Liengme	1983	12.92	-	-	-	-	0	12.92
Ciskei - Lujiko	Eberhard	1986	13.02	1.44	1.04	0	0	0	15.50
Transkei - Manzimahle	Eberhard	1986	11.05	1.13	1.59	0.15	0.02	0	13.94
Transkei - Clarkabury	Eberhard	1986	8.23	2.77	0.85	0.80	0.08	0	12.73
Transkei - Nkanga	Eberhard	1986	8.47	1.51	0.37	0	0.01	0	10.36
Gazankulu - Cottondale	Eberhard	1986	9.72	0.34	0.89	2.23	0.08	0	13.25
Lebowa - Mokumuru	Eberhard	1986	11.14	1.30	0.37	0.11	0	0	12.91
Bophuthatswana - Bodibe	Eberhard[1]	1991	4.03	6.72	0.89	1.62	0	0	13.26
Bophuthatswana - Madutle	Eberhard[1]	1991	5.13	1.16	0.52	0.08	0	0	6.90
Bophuthatswana - Dinokana	Eberhard[1]	1991	6.38	0.28	0.70	0.59	0	0	7.95
Bophuthatswana - Ganyesa	Eberhard[1]	1991	5.05	-	1.55	0.32	0.20	0	7.12
Bophuthatswana - Deerward	Eberhard[1]	1961	8.25	4.88	1.67	0.35	0.20	0	15.34
Bophuthatswana - Loopeng	Eberhard[1]	1991	13.12	2.65	1.07	0.30	0.18	0	17.32
Bophuthatswana (rural average)	Eberhard[1]	1991	6.87	2.88	1.07	0.38	0.14	0	11.34
Early Urban Transitional Stage									
Natal - Vulindlela	Eberhard	1986	12.61	-	0.63	0.14	0.02	0	13.40
Qwa Qwa	Eberhard	1986	0.66	-	1.00	8.32	0.09	0	10.07
Bophuthatswana - Amatelang	Eberhard	1986	0.44	-	1.37	5.27	0.06	0	7.16
Cape - New Bethesda	Eberhard	1986	11.02	-	2.00	1.46	0.19	0	14.66
Cape - Crossroads	Eberhard	1986	3.62	0	3.55	5.86	0.08	0	13.12
Cape (old informal)	Viljoen	1990	1.24	0	3.07	0	0.82	0	5.13
Cape (new informal)	Viljoen	1990	3.59	0	3.00	0	0.87	0	7.45
Cape (average)	Viljoen	1990	0.88	0	2.26	0	1.43	0.90	5.47
Transvaal (new informal)	Viljoen	1990	2.65	0	1.70	10.94	0.61	0	15.90
Natal - Mariannhill (peri urban)	Rivett-Carnac	1990	-	-	-	-	-	-	-
Natal - Mariannhill (t'ship non e.)	Rivett-Carnac	1990	-	-	-	-	-	-	-
Bophuthatswana - Mmabatho	Eberhard[1]	1991	2.28	-	1.26	1.59	0.15	-	5.28
Late Urban Transition Stage									
Cape (old formal)	Viljoen	1990	0	0	1.44	-	1.19	1.98	4.61
Cape (new formal)	Viljoen	1990	0.53	0	2.29	-	2.96	0.55	6.33
Natal - Mariannhill (t'ship elec.)	Rivett-Carnac	1990	-	-	-	-	-	-	-

Note: 1. Eberhard (1991) is short for Eberhard and Dickson (1991).

Table 4.15: Useful domestic nett energy consumption per household per year in total samples

Area	Source	Date	Wood (GJ)	Dung (GJ)	Paraffin (GJ)	Coal (GJ)	Gas (GJ)	Electricity (GJ)	Total (GJ)
Rural Transition Stage									
Lesotho - Malefiloane	Best	1979	3.32	1.62	0.49	-	-	0	5.43
Transkei - Jozanna's Nek	Best	1979	3.77	0.76	1.18	-	-	0	5.71
KwaZulu - Mashunka	Best	1979	10.66	0	0.44	-	-	0	11.10
Gazankulu - Giyani area	Liengme	1983	12.02	-	-	-	-	0	12.02
Ciskei - Lujiko	Eberhard	1986	7.52	0.80	2.41	0	0	0	[illegible]
Transkei - Manzimahle	Eberhard	1986	6.29	0.55	3.53	0.10	0.06	0	10.53
Transkei - Clarkebury	Eberhard	1986	6.08	1.57	2.57	0.72	0.35	0	11.31
Transkei - Nkanga	Eberhard	1986	8.35	1.28	1.55	0	0.15	0	11.32
Gazankulu - Cottondale	Eberhard	1986	7.91	0.27	3.09	2.24	0.32	0	13.83
Lebowa - Mokumuru	Eberhard	1986	6.45	0.65	0.96	0.07	0	0	8.14
Bophuthatswana - Bodibe	Eberhard[1]	1991	3.06	1.73	2.29	1.48	0	0	8.56
Bophuthatswana - Madutle	Eberhard[1]	1991	4.39	0.84	1.52	0.08	0	0	7.12
Bophuthatswana - Dinokana	Eberhard[1]	1991	5.48	0.17	2.55	0.71	0	0	8.92
Bophuthatswana - Ganyesa	Eberhard[1]	1991	2.70	-	3.33	0.29	0.68	0	7.00
Bophuthatswana - Deerward	Eberhard[1]	1991	6.17	2.37	4.72	0.34	0.71	0	14.31
Bophuthatswana - Loopeng	Eberhard[1]	1991	8.79	1.32	3.20	0.31	0.91	0	14.53
Bophuthatswana (rural average)	Eberhard[1]	1991	5.20	1.18	3.00	0.41	0.47	0	10.25
Early Urban Transitional Stage									
Natal - Vulindlela	Eberhard	1986	11.52	-	2.39	0.13	0.15	0	14.18
Qwa Qwa	Eberhard	1986	0.76	-	2.50	6.73	0.38	0	10.36
Bophuthatswana - Amateiang	Eberhard	1986	0.58	-	2.90	4.04	0.21	0	7.73
Cape - New Bethesda	Eberhard	1986	6.72	-	4.59	1.14	0.15	0	12.60
Cape - Crossroads	Eberhard	1986	3.37	0	12.56	6.29	0.41	0	22.64
Cape (old informal)	Viljoen	1990	-	0	8.23	0	2.62	0	10.85
Capa (new informal)	Viljoen	1990	-	0	5.44	0	1.88	0	7.32
Cape (average)	Viljoen	1990	-	0	6.18	0	4.70	3.47	14.35
Transvaal (new informal)	Viljoen	1990	1.68	0	3.53	8.97	1.53	0	15.71
Natal - Mariannhill (peri urban)	Rivett-Carnac	1990	-	-	-	-	-	-	-
Natal - Mariannhill (t'ship non e.)	Rivett-Carnac	1990	-	-	-	-	-	-	-
Bophuthatswana - Mmabatho	Eberhard[1]	1991	2.01	-	4.31	1.62	0.59	-	8.53
Late Urban Transition Stage									
Cape (old formal)	Viljoen	1990	0	0	5.00	0	4.91	9.54	19.45
Cape (new formal)	Viljoen	1990	-	0	5.98	0	9.26	2.02	17.26
Natal - Mariannhill (t'ship elec.)	Rivett-Carnac	1990	-	-	-	-	-	-	-

Note: 1. Eberhard (1991) is short for Eberhard and Dickson (1991).

Table 4.16: Useful domestic energy consumption per capita per year in total samples

Area	Source	Date	Wood (GJ)	Dung (GJ)	Paraffin (GJ)	Coal (GJ)	Gas (GJ)	Electricity (GJ)	Total (GJ)
Rural Transition Stage									
Lesotho - Ma'efiloane	Best	1979	0.64	0.31	0.90	-	-	0	1.85
Transkei - Jozanna's Nek	Best	1979	0.60	0.10	0.19	-	-	0	0.89
KwaZulu - Mashunka	Best	1979	2.48	0	0.11	-	-	0	2.59
Gazankulu - Giyani area	Liengme	1983	1.68	-	-	-	-	0	1.68
Ciskei - Lujiko	Eberhard	1986	1.69	0.14	0.52	0	0	0	2.35
Transkei - Manzimahle	Ebarhard	1986	1.44	0.11	0.80	0.02	0.01	0	2.38
Transkei - Clarkebury	Eberhard	1986	1.07	0.28	0.43	0.12	0.05	0	1.94
Transkei - Nkanga	Eberhard	1986	1.10	0.15	0.19	-	0.01	0	1.45
Gazankulu - Cottondale	Eberhard	1986	1.26	0.03	0.44	0.33	0.05	0	2.12
Lebowa - Mokumuru	Eberhard	1986	1.45	0.13	0.19	0.02	0	0	1.79
Bophuthatswana - Bodibe	Eberhard[1]	1991	0.52	0.67	0.44	0.24	0	0	1.87
Bophuthatswana - Madutle	Eberhard[1]	1991	0.67	0.12	0.26	0.01	0	0	1.05
Bophuthatswana - Dinokana	Eberhard[1]	1991	0.83	0.03	0.35	0.09	0	0	1.30
Bophuthatswana - Ganyesa	Eberhard[1]	1991	0.66	-	0.78	0.05	0.12	0	1.60
Bophuthatswana - Deerward	Eberhard[1]	1991	1.07	0.49	0.83	0.05	0.12	0	2.56
Bophuthatswana - Loopeng	Ebarhard[1]	1991	1.71	0.27	0.54	0.04	0.11	0	2.66
Bophuthatswana (rural average)	Eberhard[1]	1991	0.89	0.29	0.54	0.06	0.08	0	1.85
Early Urban Transitional Stage									
Natal - Vulindlela	Eberhard	1986	1.64	-	0.31	0.02	0.01	0	1.99
Qwa Qwa	Eberhard	1986	0.09	-	0.50	1.25	0.05	0	1.89
Bophuthatswana - Amatelang	Eberhard	1986	0.06	-	0.68	0.79	0.05	0	1.58
Cape - New Bethesda	Eberhard	1986	1.43	-	1.00	0.22	0.11	0	2.76
Cape - Crossroads	Eberhard	1986	0.47	0	1.78	0.88	0.05	0	3.18
Cape (old informal)	Viljoen	1990	0.16	0	1.54	0	0.49	0	2.19
Cape (new informal)	Viljoen	1990	0.47	0	1.50	0	0.52	0	2.49
Cape (average)	Viljoen	1990	0.11	0	1.13	0	0.86	0.63	2.73
Transvaal (new informal)	Viljoen	1990	0.34	0	0.85	1.64	0.36	0	3.20
Natal - Mariannhill (peri urban)	Rivett-Carnac	1990	-	-	-	-	-	-	-
Natal - Mariannhill (t'ship non e.)	Rivett-Carnac	1990	-	-	-	-	-	-	-
Bophuthatswana - Mmabatho	Eberhard[1]	1991	0.30	-	0.63	0.24	0.09	-	1.25
Late Urban Transition Stage									
Cape (old formal)	Viljoen	1990	0	0	0.72	0	0.71	1.38	2.82
Cape (new formal)	Viljoen	1990	0.07	0	1.15	0	1.78	0.39	3.38
Natal - Mariannhill (t'ship elec.)	Rivett-Carnac	1990	-	-	-	-	-	-	-

Note: 1. Eberhard (1991) is short for Eberhard and Dickson (1991).

The information in the final columns of tables 4.14 and 4.16 is used in section 6.1.1 to identify energy poverty in South Africa. At this point it is sufficient to note that levels of energy consumption in many of the samples are below the two energy poverty lines used in this study, namely:

- 10 GJ of nett energy per capita per year
- 1.5 GJ of useful energy per capita per year.

Note that if the data in each of the above tables were to be organised in the three energy transition categories according to the totals in the final column, the change in the 'ranking' of various samples between tables 4.13 and 4.14, and between tables 4.15 and 4.16 would be ascribable to variations in household size. Yet changes in the ranking of samples between tables 4.13 and 4.15, and tables 4.14 and 4.16 would be due to differences in the efficiency of the energy sources households use. The impact that energy-use efficiency has on household welfare is discussed in section 6.2.1.4, but it is worth noting here that in the domestic energy transition process as a whole there is a gradual shift towards the use of more efficient energy sources. This is illustrated in the graphical presentation of table 4.16 below.

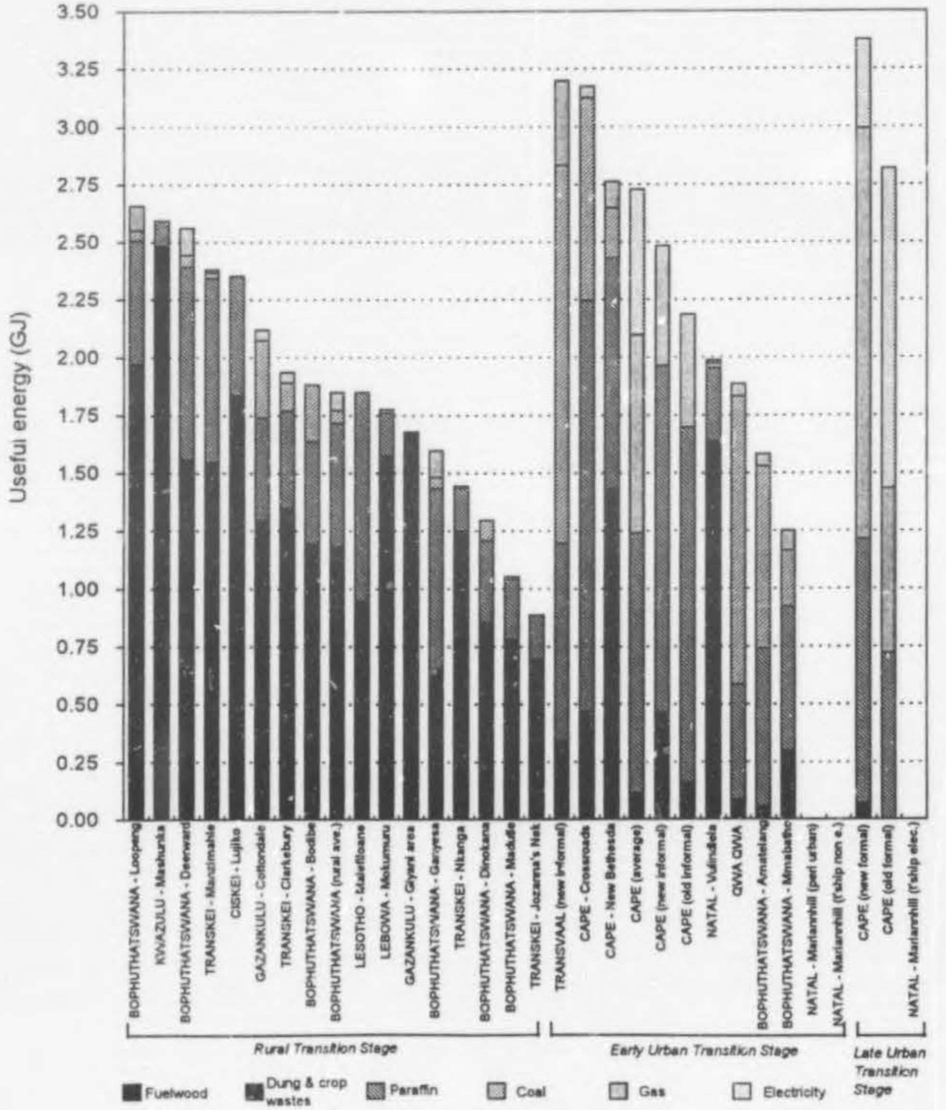


Figure 4.6: Useful domestic energy consumption per capita per year in total samples

It is evident that in the rural energy transition households obtain most of their useful energy from fuelwood and dung, which have very low energy-use efficiencies. The gradual shift towards coal, paraffin and gas that takes place in the late rural and early urban energy transition stages entails a shift towards more efficient energy sources as well. The shift to electricity in the late urban energy transition represents yet a further gain in energy-use efficiency.

The above figure also highlights trends in the overall availability and versatility of energy sources consumed by households at different stages of the domestic energy transition process. As regards the former, the overall trend is towards greater availability of energy. In the rural transition households have to collect fuelwood from their environs, in the next stage energy sources may be purchased from shops and in the late urban transition electricity is actually delivered to the home. However, these improvements in availability are tempered by affordability: in the late rural and early urban transition stages the decline in the availability of fuelwood is compensated by an increase in the availability of paraffin, coal and gas, but since many households cannot afford these energy sources they either resort to using dung or consume less energy. The *de facto* availability of energy may be said to decline during these stages. A similar situation exists in areas where electricity is available to households, but some of them cannot afford the access fee or the appliances required to utilise it.

As regards versatility, there is also an improving trend across the entire domestic energy transition. Indeed the gains made, say, from being reliant on fuelwood to using electricity, are enormous. However, dung, as noted in section 4.2, is not as versatile as fuelwood. In the early urban transition and immediately after electrification households may have access to versatile energy sources but may not be able to realise this potential due to the cost of appliances. Households may, therefore, experience a fall in the range of energy services available to them when shifting from one energy source to another. Most notable is the loss of the space warming effect of the open hearth when households use a primus stove.

There are a number of other trends in the characteristics of the energy sources used at different stages of the domestic energy transition process that are relevant to household welfare:

- There is a gradual progression from free access to the commercialisation of energy sources. In the early stages of the rural transition access to biomass energy sources does not require cash, but as soon as these energy sources become scarce they tend to become commercialised. So from the late rural transition right through the rest of the process the energy sources available to households are commercialised. This means households have to devote a certain percentage of their income to purchasing energy. Factors such as price, income and substitution effects, opportunity costs, etc. therefore become more important in determining the welfare impact of consuming energy. These factors are discussed in various places in section 6.2.1.

- There is a trend towards more convenient energy sources. Clearly the transitions from fuelwood to paraffin to gas and, finally, to electricity represent shifts that bring greater convenience and, hence, improvements in household welfare. Dung and coal are not convenient energy sources and their use may be depicted as deviations from the overall trend. Their contribution to household welfare in the area of convenience is probably small, if not negative.
- Initially, the domestic energy transition process is moved forward by a lack of alternatives as fuelwood resources are depleted. Consequently, households are forced to use dung and crop wastes. Thereafter, the process moves forward because households have greater choice as determined by improvements in income, access and changes in locality;
- The energy sources households use tend to become successively cleaner as the transition process progresses. This enhances household welfare by improving the quality of the health and amenity services of the home environment. These aspects of the energy transition are discussed in section 5.1 Again dung and coal are deviations in the overall trend,
- There is a trend from biomass to fossil fuels or, alternatively, from renewable to non-renewable energy sources. This aspect of the energy transition is also referred to at various stages in section 5.1.

CHAPTER 5

THE ENVIRONMENTAL EFFECTS OF DOMESTIC ENERGY TRANSITION

The term environment in this study, as noted in section 1.3.2, is given the meaning it bears in popular usage: to refer to the air, water and soil, plants and animals, habitats and ecosystems. It was also noted the environment is a natural asset or non-reproducible capital good from which people derive various economically valuable direct and indirect services. Very briefly these services include the support of human life (and life in general), the supply of material inputs or resources, the removal, storage or assimilation of residuals or wastes, and the provision of amenity opportunities (Freeman *et al.*, 1973:20).

The utilisation of these environmental services is an integral aspect of household welfare, but is also a cause for concern. Excessive utilisation of environmental services may lead to the destruction of the natural capital stock which provide the services - rendering them incapable of providing a particular service or causing a drop in the quality of services. To ensure the continued supply of environmental services for the purpose of development, the natural capital stock needs to be conserved. Community development and environmental conservation are thus interdependent (section 1.3).

The present chapter investigates aspects of this interdependence within the context of the domestic energy transition process. Specific attention is given to the effects different patterns of energy production and consumption for domestic purposes have on the environment and the impacts these environmental effects have in turn on individual and household welfare. The aim of this analysis is to give an overview and assessment of the relative importance of the environmental impacts of energy use. A comprehensive analysis is beyond the scope of this study. The more direct effects of energy use on household welfare are investigated in chapter 6.

The rest of chapter 5 is divided into three sections. Section 5.1 gives attention to the effects different fuel types have on the environment. It is a lengthy section since each fuel is treated separately. Section 5.2 looks at the potential that energy conservation in the domestic sector has for reducing the negative environmental impacts of energy use. Finally, in section 5.3 the environmental effects which occur in the different phases of the standard model (section 2.3.3) are identified and overall trends in their occurrence are analysed.

5.1 Energy sources and the environment

In this section the specific links between the environment and different domestic energy sources used by households are examined The aims of the section are:

- to identify and discuss the environmental impacts of different domestic energy sources;
- to survey the extent of these impacts within South Africa and to identify gaps in our knowledge; and
- to facilitate comparisons between the impacts of different energy sources within the context of the domestic energy transition process. More attention is given to these comparisons in section 5.3 below.

The structure of the section is straightforward: for instance, in section 5.1.1 that discusses the impact that the domestic use of fuelwood has on the environment, the positive environmental effects of consuming fuelwood are noted first and then the main negative impacts. Successive sections discuss fuelwood, dung, paraffin, coal and gas, as well as some minor fuels in this way. In section 5.1.7 the approach is somewhat different: attention is given to the environmental impacts of domestic electricity use in sub-sections on consumption, transmission and generation. Since the impacts of generating electricity are largely dependent on the energy sources used, the last sub-section looks at coal, nuclear and hydro generation, as well as some other methods, separately.

The range of information covered in this section is vast. Too much detail would therefore defeat one of the overall aims of the study, which is to create a synthesis of existing information that will enable the broader issues and trends within the process of domestic energy transition to be identified.

5.1.1 Fuelwood

The positive environmental impacts of using fuelwood as a domestic energy source fall into three categories:

(i) *Relative cleanliness* Fuelwood is a relatively clean fuel when compared to coal. It emits less sulphur dioxide, carbon dioxide and particulates per unit energy than coal and so the environment is able to dispose of or neutralise wood smoke more easily than coal smoke (Lennon and Turner, 1991:8). However, fuelwood is obviously not as clean as gas, biogas, paraffin and electricity.

(ii) *Spread of discharges* Fuelwood emissions are released into the environment at the point of combustion. Since fuelwood is used throughout the rural and peri-urban areas of South Africa, the emissions are similarly spread. As a result they tend not to overload the environment's waste disposal service in any one place. This is in sharp contrast to the use of coal for generating electricity on the Mpumalanga Highveld.

(iii) *Renewable resource* Fuelwood is a renewable energy source, but only to the extent that the resource base responsible for its regeneration remains intact. Most fuelwood in

South Africa is harvested from woodland and shrubland, with smaller amounts being obtained from indigenous forests, self-seeded exotics, woodlots, plantations and alien vegetation eradication. In many areas the regenerative capacity of the woodland/ shrubland resource base has been either wiped out or severely damaged due to excess utilisation by an ever increasing population (Wilson and Ramphele, 1989:44-46). So in most areas of South Africa fuelwood is only a potentially renewable resource. The phenomenon of deforestation and fuelwood scarcity is discussed further below, as well as in section 3.2.5.

The negative environmental impacts of using fuelwood are associated with air pollution and with the loss of tree cover/deforestation.

(iv) *Air pollution* The combustion of fuelwood emits mainly particulates, carbon dioxide, carbon monoxide and nitrogen oxides (Morris, 1982:435). These emissions contribute to the macro level environmental impacts of global warming (carbon dioxide is the principal 'greenhouse' gas), photochemical smog and acid rain (of which nitrogen oxides are key ingredients). Even though the total stream of wastes generated by the domestic use of fuelwood in South Africa is minute in global terms, this does not detract from their importance - small links add up to big ones. The emissions are also significant in so far as they can be reduced at reasonable cost or effort.

The environmental impacts are more obvious at the intermediate level. The smoke from cooking fires contributes to the significant levels of neighbourhood air pollution experienced in many peri-urban and township areas. The particulates may cause eye irritations and sinusitis, and aggravate respiratory conditions such as asthma. Some of the emissions are also carcinogenic, which increases the risk of cancer (Morris, 1982:436).

The micro impacts are more serious than both the above levels of impacts. When fires are lit in poorly ventilated cooking areas or inside dwellings the resulting concentrations of wastes may be very high. Regular exposure to such pollution may have serious consequences on people's health. Women are particularly at risk because of the amount of time they spend cooking and tending the fire.

In colder areas people often endeavour to conserve heat by sealing the cold out (and the smoke in) and by sleeping next to the hearth or brazier. This practice exposes people to the risk of carbon monoxide poisoning which may cause brain damage or even death.

Ways of ameliorating many of these impacts are discussed in section 7.1.1(c), which examines the problems of indoor pollution typically experienced by many rural households.

(v) *Loss of tree cover/deforestation* Ideally, fuelwood gathering should be confined to dead wood. No trees would then be destroyed and the natural balance of the forest or woodland ecosystems would remain largely intact. The long term supply of fuelwood would also not be jeopardised by any reduction in the size of the resource base.

The loss of tree cover can be depicted as a process with four stages. The first stage is characterised by a plentiful supply of wood, but there is a transition from the practice of removing dead wood only to the removal of live branches and the cutting down of trees as well. Initial impacts may be almost imperceptible, but they add up. Particular species of trees, especially ones with desirable fuelwood qualities, will become scarce. Trees of a particular size may also become scarce - usually those from 10 to 20 centimetre in diameter, since they make good fuelwood. The largest trees are not often cut down simply because it would take too much effort. Large trees may also be regarded as valuable for shade or for other reasons. In the second stage trees in the immediate vicinity of dwellings become scarce. They are the most easily harvested and therefore the first to disappear. In general, however, fuelwood is still readily available. The third stage is reached when fuelwood supplies within a radius of about 3 km of dwelling places have been depleted. In other words, to fetch a headload of fuelwood entails a walk further than 6 km (Gandar, 1984:3). In such circumstances the loss of tree cover is serious, especially in areas where rural communities are seldom further than 7 km apart. The fourth and final stage is characterised by the almost total disappearance of trees. Some trees may still be found in deep ravines and on mountain slopes, but even their existence is at risk (Wilson and Ramphele, 1989:44).

Rapid increase in population places pressure on all natural resources and is the main driving factor behind deforestation and the loss of tree cover. This is confirmed by Aron *et al.* (1989). They project that by the year 2000 the demand for fuelwood will exceed the overall sustainable supply in the former homeland areas of Bophuthatswana, Kwandebele, KwaZulu, Lebowa, Qwa Qwa, Transkei and Venda, due to increases in population. However, the situation is already serious in many localities where the sustainable yield is already being exceeded, resulting in the depletion of local tree stock. A wide ranging survey of fuelwood use by Eberhard (1986:34) shows that in many areas women walk an average of 9.4 km to gather fuelwood. In these areas the loss of tree cover has reached the third of the stages described above.

Gandar (1991:96) is correct in pointing out that while fuelwood gathering is probably the dominant cause, it is not the only activity responsible for the growing scarcity of trees. Other human activities also exact a toll. The clearance of virgin land to provide land for settlement and agriculture has significantly reduced the area covered by natural bush. Stock farming damages the resilience of the natural tree cover, especially where goats browse and break the younger trees or where there is overgrazing. Even the collectors of natural medicines harm tree stocks by removing so much bark from trees that they are unable to survive. Then there are the more direct uses of wood in construction and fencing, but their contribution is small and declining. Studies indicate that in most areas less than 10% of all the wood harvested by rural households is devoted to these latter two uses, and as fuelwood shortages occur the amount falls rapidly (Aron *et al.*, 1989:24).

The loss of tree cover/deforestation is an important impact in itself, but because trees are such vital links in so many biophysical and ecological processes, it has far wider consequences. The more important of these are noted: firstly, trees by the process of photosynthesis convert carbon dioxide into oxygen. The loss of tree cover reduces the environment's capacity to deliver this vital service. Excess carbon dioxide contributes to global warning, which may severely disrupt the environment's capacity to sustain life. The environment's capacity to absorb carbon dioxide is reduced by 50 000 tonnes for every million trees destroyed (Clarke, 1991:154). At a very rough estimate, in the order of 20 million trees are being destroyed each year for fuelwood in the former homeland areas alone. (This figure is based on Aron *et al.*'s fuelwood consumption figures. It is assumed that 50% of the fuelwood comes from live trees and that each tree supplies 125 kilograms of wood.) Secondly, trees maintain the quality of soil by rejuvenating it with nutrients and humus and by preventing it from eroding. The loss of trees exposes soil to the full force of wind and falling rain and reduces its absorptive capacity. The soil is also no longer bound together by trees' root systems. As a result the rate of run-off increases, farming land is exposed to erosion, the water table drops, rivers tend to flood and desiccate alternately, and dams silt up. Generally ground and surface water hydrology is disrupted. Thirdly, the loss of trees, along with overgrazing, is hastening the process of Karoo encroachment or desertification, which drastically reduces the land's capacity to support any sort of farming activity. Lastly, the loss of tree cover means that whole ecosystems are destroyed and along with them the habitats of many valuable plants and animals.

Loss of tree cover/deforestation caused by fuelwood gathering is a problem that needs to be addressed both from the demand side and from the supply side. This is the approach adopted in section 7.1.1(b), where ways of reducing and possibly even reversing the impact that the loss of tree cover is having on the environment are discussed, along with a range of policy suggestions and recommendations.

5.1.2 Dung/crop wastes

In South Africa dung and crop residues are fuels of last resort. Only households faced with truly critical energy shortages use these materials. Their use is, therefore, not widespread, although in particular localities they are important (Gandar, 1984:7). The positive environmental effects of using dung and crop residues are similar to those of fuelwood, but certainly not as significant. They burn more cleanly than coal, but not as cleanly as fuelwood. These materials, like wood, are also renewable energy resources, and when burnt their emissions are spread over a wide area.

The negative environmental impacts of burning dung and crop residues centre around air pollution and the loss of nutrients from the soil.

(i) *Air pollution* Dung and crop residues combust at relatively low temperatures, therefore, under the best circumstances they smoke profusely and even more so when slightly damp. Exposure to this smoke on a regular basis has similar health implications as wood smoke. The risks are aggravated somewhat by households trying to conserve energy and so burning these materials indoors with minimal ventilation. From the macro perspective the quantity of waste originating from the burning of dung and crop residues is very small and only important in so far as it is preventable.

(ii) *Loss of nutrients* Burning dung and crop residues as fuel sets a dangerous cycle of impoverishment of soil nitrogen, potassium, phosphorous and humus in motion - dangerous because the soil becomes progressively less productive and more susceptible to wind and water erosion (Rivett-Carnac, 1982:20).

In South Africa the use of dung has not nearly reached such dimensions. Indeed the amounts used are so small that Gandar (1984:7) argues that "the environmental effect of this micro interruption of the nutrient cycle is negligible" and that the direct loss to agriculture is even smaller since only a tiny minority of farmers use dung to fertilise fields.

In some areas it may also be possible to use dung and crop wastes, as well as human excreta, to produce biogas. Biogas is derived from the anaerobic decomposition of organic materials. The end product of the process is, therefore, a rich organic fertiliser that can be applied directly to fields, which means no nutrients are lost. If anything the nutrient cycle is more complete since the process renders excreta safe to use on fields. In China and India the improvements in rural sanitation and health that are made possible by biogas converters are regarded as important secondary benefits, after the production of a clean fuel and the conservation of nutrients. Further details regarding the feasibility of biogas in South Africa are discussed in section 7.2.4

5.1.3 Paraffin

The benefits of using paraffin are greatest when it replaces fuelwood, dung and crop residues. Compared to these biomass fuels paraffin burns more cleanly and efficiently. In general, emissions per household are low because not much is consumed. They are therefore only important to the extent that they are preventable. Paraffin emissions also occur at the point of use, which means they are spread over a wide area.

In addition the domestic use of paraffin alleviates pressure on tree stocks and reduces the destruction of nutrients in so far as it replaces the biomass fuels. The use of paraffin should be encouraged in these circumstances.

The negative environmental impacts of paraffin use centre around air pollution and the fact that it is a non-renewable energy source.

(i) *Air pollution* Paraffin emissions include hydrocarbons, carbon dioxide, carbon monoxide and nitrogen oxides. How much of each is discharged during combustion depends on factors such as the type of appliance and the efficiency with which it operates, the temperature of combustion and air pressure.

The macro impacts of these emissions are very small indeed. The carbon dioxide contributes to global warming, the hydrocarbons and nitrogen oxides to photochemical smog and low level ozone, while carbon monoxide is toxic. The micro level impacts tend to be more significant. Using paraffin in enclosed environments exposes the members of households to above average levels of pollutants on a regular basis. This may impair the ability to concentrate, aggravate respiratory problems and cause eye irritations.

(ii) *Non-renewable resource* Paraffin, like all petroleum products, is a non-renewable energy resource. Despite the upward trend in consumption since 1980, the total amount consumed scarcely affects the rate at which global oil reserves are being depleted.

(iii) *Other impacts* The consumption of paraffin contributes in a small way to the environmental impacts of the oil industry as a whole. These include pollution during the extraction, transportation and refining of oil and more particularly of paraffin, as well as the washing/disposal of containers used to distribute it. The percentage of these impacts that may be directly attributable to paraffin cannot be regarded in isolation; they are part of the way energy supply and use is presently structured. A meaningful reduction in the environmental impacts of the oil industry is unlikely unless the structure of energy supply and use moves towards using renewable resources and conserving energy - i.e. towards sustainable living practices.

5.1.4 Coal

Only the environmental impacts of domestic coal consumption are of concern here. The impacts associated with the coal generation of electricity are discussed in section 5.1.7.3(a).

The domestic sector's demand for coal constitutes about 1% to 1.5% of South Africa's total coal production. In 1991 this represented in physical terms between 1.5 and 2.3 million tonnes of coal (Eberhard and Trollip, 1992:23). Compared to the 70 million tonnes burned by Eskom in the same year, this is not very much coal (Eskom, 1992:28). Domestic coal consumption depends *inter alia* on its availability and cost. Households using coal are, therefore, concentrated in and around the coalfields. Transport costs tend to push the price beyond people's means in areas far removed from the coalfields. This is reflected in the following figures: in 1991 the annual per capita consumption of coal in KwaZulu-Natal was about 9 kilograms, in the Gauteng region it was just less than 6 kilograms, while in the Cape Town area the amount was negligible (Eberhard and Trollip, 1992:23). Climate also affects the domestic demand for coal.

The only positive environmental impact of domestic coal use would appear to be that it alleviates pressure on tree stocks, but this only represents a gain in so far as coal replaces fuelwood as an energy source. The fact that the emissions from the domestic use of coal are spread over a large area is not considered to be an advantage, as it is in the case of other fuels. The reason is that coal fires emit substantially more particulates and sulphur dioxide, which can be more effectively controlled if the coal were burnt at a central point, as when generating electricity (Lennon and Turner, 1991:8).

Most of the negative environmental impacts of domestic coal use centre around air pollution. The macro impacts arising from coal emissions are more closely associated with the coal generation of electricity which are discussed in section 5.1.7.3(a). Only the micro level impacts of domestic coal use are discussed below.

(i) *Air pollution* The real significance of the domestic use of coal lies in the impact the emissions have at the intermediate and micro levels. The quantity of waste emitted usually exceeds the local environment's capacity to absorb and disperse it. Consequently, the quality of the air both within and around the household is reduced. The impact on the indoor environment depends on whether the coal is burnt in a stove or a brazier or on an open fire, on the efficiency of the appliance (where one is used), on the quality and quantity of coal used and on the degree of ventilation. The season and outside temperature are secondary determinants since they affect the level of pollution via the other factors. For instance on a cold night a household will burn more coal and try to conserve heat by reducing ventilation. Both these measures will tend to aggravate indoor pollution. The extent of indoor pollution may vary very rapidly since the body of air in a dwelling can be replaced quickly if a window is opened, but just as quickly polluted if it is closed again. Data on indoor pollution should, therefore, reflect both long term aggregate levels, as well as short term peaks. Figures on neighbourhood pollution (given below) suggest that aggregate levels of indoor pollution are high. Short term levels are sometimes so high as to be debilitating or even fatal.

Coal emissions affect the quality of the indoor environment by impairing the life support service people derive from it. In the extreme carbon monoxide poisoning may occur when people sleep next to a coal fire in a room with poor ventilation. Carbon monoxide reduces the oxygen-carrying capacity of the blood. A few hours exposure to high concentrations can cause brain damage and even asphyxiation (American Chemical Society, 1978:163). Other health impacts associated with indoor coal emissions include the aggravation of respiratory diseases, irritation of eyes and the impairment of people's ability to concentrate. Some of the components of coal smoke are also carcinogenic and regular exposure increases the risk of cancer. People most likely to be affected by indoor pollution are the aged, children and sufferers of asthma, bronchitis, emphysema and cardiovascular illnesses (American Chemical Society, 1978:162). In Soweto it appears that children living in polluted home environments are more susceptible to diseases, especially acute respiratory infections (Lawson, 1991:57). All these impacts are known to increase morbidity and mortality rates, but to what extent has not been determined because of the difficulty of quantifying health impacts.

Coal emissions also reduce the amenity of the indoor environment. Breathing in particulates is unpleasant and the odour of coal smoke is disagreeable and may be nauseating to some people. The precipitation of particulates also covers everything in a fine layer of dust, reducing the general level of cleanliness.

Emissions from the domestic use of coal are a major source of intermediate or neighbourhood air pollution. The problem is most acute in townships that are not electrified, but even those with electricity are affected by pollution 'spillover' from other areas and because many households in backyard shacks are not connected. In addition many households with electricity still use coal stoves. Emissions are also usually greatest in densely populated areas, which increases both the concentration of the pollution and the number of people exposed to it. The fact that domestic coal smoke is released at low level aggravates neighbourhood air pollution. Other aggravating factors include temperature, local climatic and wind conditions, the grade of coal consumed, household cooking patterns and the appliance or method used to burn coal.

It is difficult to express the dimensions of the problem of emissions, since it varies from place to place along with the above factors and is compounded by pollution from other sources. The worst pollution probably occurs in townships in Gauteng, where high levels of coal consumption on cold winter nights combine with stable air conditions and temperature inversions. Certainly, based on visibility, air pollution seems to peak in the mornings and evenings, and during the winter months. More detailed evidence is scarce, but that which is available suggests the problem is serious. Kemeny *et al.* (1988:) report that smoke pollution measured at sites in Soweto in 1982 frequently exceeded the guideline limits set by the Department of Health. Even in a paper that sets out to allay fears about the dangers of air pollution in South Africa, Lennon and Turner (1991:2) concede that the concentrations of fine particulate mass measured in Soweto "would be totally unacceptable overseas". They also report that concentrations of sulphur dioxide and nitrogen oxides in Soweto are 2.5 and 3 times greater respectively than on the Mpumalanga Highveld, but in neither instance do they exceed the long term guideline limits. Tyson *et al.* (1988:40) stress the relative importance of low level emissions from domestic coal use, even though "domestic/municipal combustion" contributes only about a twentieth of the emissions on the Mpumalanga Highveld.

Neighbourhood pollution inhibits the supply of various environmental services. It reduces the quality of life support services. As a result people's health may be affected in many of the ways already mentioned. These impacts tend to be less acute than indoor pollution, since ambient levels of air pollution are lower in the former instance. The amenity of the residential environment is also impaired in ways similar to those described above. The grey smoky haze is an additional amenity reducing impact. Air pollution also affects buildings and other structures. Tyson *et al.* (1988:73) report that galvanised steel used in low cost housing schemes is particularly susceptible to corrosion by sulphur dioxide. The useful life of this material may be nearly halved due to air pollution. Other materials such as concrete, bricks and paintwork are affected as well - necessitating more frequent maintenance. It is also highly likely that air pollution damages the plants and trees in townships, since far lower concentrations than occur in these areas are known to have adverse effects on crops and forests (Tyson *et al.*, 1988:87 and 92).

(ii) *Solid wastes* Apart from air-borne emissions, the use of coal also generates a stream of solid wastes. Where this waste is simply dumped in the open it may continue to smoulder, adding to pollution, and the wind may spread it, covering everything in an unpleasant and unsightly fine grey dust. This problem could be solved at no cost and with minimal effort if households would bury coal ash in a garden refuse pit or dispose of it along with other household refuse.

(iii) *Other impacts* The domestic use of coal contributes in a small way to the environmental damage caused by coal mining and to the depletion of a non-renewable resource. Both these impacts need to be addressed at an industry level. It has been suggested that a carbon tax is an appropriate method of forcing the price of coal to reflect its true marginal social cost (assuming this is known). The resulting rise in the coal price would make renewable energy systems more competitive, which would hasten their development and adoption and, thus, move the economy closer to a sustainable development path.

Ways of reducing the environmental impacts resulting from the domestic use of coal are discussed in section 7.1.3(a). The recommendations on ways to conserve energy in section 7.2 are also relevant.

5.1.5 Gas

The gas used by households in South Africa is almost entirely liquid petroleum gas (LPG). Despite the relatively small amounts of gas consumed, it is an important fuel because of the environmental benefits associated with its use.

(i) *Few emissions* Gas is the cleanest of the hydrocarbons. Particulate and sulphur dioxide emissions are minimal, while those of nitrogen oxides are comparable to coal and oil (Vohra, 1982:87). The combustion of gas also generates up to two-thirds less carbon dioxide than coal (Rogner, 1989:62). The domestic use of gas has no noticeable negative impacts on the home and neighbourhood environment. At the macro level gas has definite advantages: it contributes less to global warming and acid rain than any other carbon fuel (Rogner 1989:62). Indeed Flavin (1992:34) notes that heating with gas "is in most circumstances less polluting than heating with electricity produced from coal or oil."

(ii) *Efficiency* Gas appliances generally have higher thermal conversion efficiencies than those of other fuels, i.e. gas appliances convert a greater proportion of the nett energy available in gas into useful energy than, say, paraffin appliances do with paraffin. For instance, for a gas stove the thermal efficiency may be as high as 75%, compared to 50% and 20% for paraffin and coal stoves (Viljoen, 1990:83). Similarly, in the generation of electricity combined-cycle gas turbines have thermal efficiencies of 47%, which is a significant improvement on the 34% of Eskom's coal power stations in 1991 (Rogner, 1989:60; Eberhard and Trollip, 1992:27).

(iii) *Low risks* Estimates of the health and other risks of different energy sources have shown that gas has the lowest overall risk associated with its use (Vohra, 1982:87). There is, nevertheless, always the possibility of accidental leakages and explosions.

(iv) *An energy bridge* People concerned about the environment regard gas as a 'bridge' from the existing fossil fuel based energy system to more sustainable energy technologies. It provides a low pollution alternative to oil and coal, while the new solar, wind, hydrogen and superconductivity technologies are developed and disseminated (Rogner, 1989: 52 and 63; Flavin, 1992: 41-43). For this reason it is suggested in section 7.1.4(c) that the domestic use of gas should be encouraged.

The main environmental objection to gas is that methane is itself a 'greenhouse' gas and so accidental leakages of it would exacerbate global warming. Such leakages are likely to increase as the use of gas increases (Flavin, 1992:37). Gas is also a non-renewable resource, but the present level of domestic consumption hardly affects the rate at which reserves are being depleted.

5.1.6 Other energy sources

Apart from the above mentioned fuels and electricity, households also use candles, wet/dry cell batteries and various solar devices. These are minor energy sources and so the extent of their negative impact on the environment is small.

Candles' impacts on the environment are comparable to those of paraffin, since they are made from paraffin wax. Candles do not convert energy into light efficiently. A paraffin lamp would probably do the job better.

Many households without access to electricity use dry/wet cell batteries. Most dry cell batteries are non-rechargeable and cannot be recycled, whereas wet cell batteries are rechargeable and some parts of them can be recycled. However, wet cell batteries are prone to the accidental leakage of battery/sulphuric acid, which may cause severe burns and pollute water. More important are the impacts that the manufacture of both types of batteries has on the environment. Some of the materials are toxic and the ratio between the energy used in manufacture and the energy delivered to the household makes them an inefficient use of energy overall.

Solar-energy is seldom purposefully used by households. In rural areas dwellings are sometimes located and designed to take advantage of the space heating properties of the sun. This means that other energy sources need not be used for this purpose, which alleviates pollution and means fewer trees are destroyed. The sun's passive heating qualities could be used more extensively in peri-urban and urban areas (section 7.2.2).

Solar-energy is also used by some more affluent households for heating water. Solar-water heaters are still costly, which limits the extent to which they are used. This is unfortunate because significant amounts of fossil and biomass energy could be saved if an affordable model were available (Eberhard, 1986:12). Once installed, a solar heater has virtually no adverse environmental impacts and it has the added advantage of demonstrating to people that sustainable energy sources are available and potentially viable (section 7.2.4).

5.1.7 Electricity

The environmental impact of the domestic use of electricity cannot be totally separated from the impacts resulting from electricity use in other sectors of the economy, e.g. industry, mining, agriculture, transport and commerce. This is because the different end uses of electricity are seldom specified during the generation and transmission processes. Nevertheless, since households consume about 15% of the electricity produced in this country (Eberhard and Trollip, 1992:19), they are responsible for at least a similar proportion of the pollution and other impacts associated with electricity use in South Africa.

Attributing at least part of the external effects of electricity use to domestic consumers reverses the prevalent trend of laying all the blame at the door of the supplier. Admittedly Eskom could have done more to reduce the negative impacts of its operations, but it also needs to be recognised that domestic consumers have resisted paying for the cost of control measures through the price of electricity and have done little to conserve energy and even less to inform themselves and lobby the government and Eskom regarding environmental impacts. There seems to be a general lack of appreciation on the part of the government, Eskom and the public for environmental issues and the integrated nature of household/community welfare and environmental welfare.

This section aims to describe the different impacts associated with the consumption, transmission and generation of electricity and to focus attention on the links or trade-offs that exist between the environmental benefits and costs of using electricity within the domestic sector. This issue is particularly relevant within the present context of rapid electrification.

5.1.7.1 The consumption of electricity

The environmental benefits arising from the consumption of electricity must be weighed-up against the negative impacts of generating and transmitting it. Households are seldom aware of this trade-off, since the benefits of consumption accrue directly to them, while the costs are imposed on others or are not immediately apparent or only affect them indirectly.

The environmental impact of each household's electricity consumption is influenced by:

- the extent to which it replaces other energy sources and which of these it replaces;

- the quantity of electricity consumed;
- the appliances used and their efficiency;
- the type/design of the dwelling;
- the extent to which energy conservation is practised; and
- people's habits and preferences in the use of energy.

These factors are in turn influenced by variables such as income, the price of electricity and of electric appliances, geographical location, climate, modernisation and lifestyle. Since all these factors and variables differ from one household to the next, so do their impacts on the environment.

The positive environmental impacts of using electricity domestically fall into two categories:

(i) *Clean energy source* In a narrow sense electricity is the cleanest domestic energy source. When it replaces coal and biomass fuels it alleviates local level pollution problems: the environment's life support service improves, which reduces the risk of respiratory problems and generally enhances people's health. The amenity services of the home environment also improve. The transition to electricity does not need to be complete for substantial improvements in environmental quality to be experienced. Improvements in environmental quality are likely to be greater when electricity replaces coal or fuelwood for cooking, space heating and heating water. Few improvements are likely where electricity replaces gas or paraffin. In effect, this means that the non-use of coal and fuelwood is more directly linked to environmental quality in and around households than the use of electricity, i.e. if the use of these two fuels could be eliminated by other means the impact would be as beneficial as when electricity is used to do so. In fact, biogas, gas and solar energy are probably cleaner substitutes than electricity when all associated impacts are taken into account, though they are not as versatile.

At present only about one third of all South Africans have access to electricity. Virtually all whites, even those in remote rural areas, have access, while only between 15% and 20% of blacks are served (Theron, 1992:10). The environmental benefits of domestic electricity consumption, therefore, accrue mainly to whites and have done so for many years. This inequality reflects yet another dimension of the patronage whites enjoyed under apartheid. The process of redressing the situation has begun with over 300 000 new, mostly black households being added to the network each year, but as yet the government has not become financially involved - as it was when whites' homes were being electrified (Stavrou, 1992:5; Opperman, 1994:3).

(ii) *Replacement of biomass fuels* Households with electricity use less biomass fuel, so electrifying townships and rural areas tends to reduce the loss of tree cover/deforestation and the destruction of nutrients. For townships these are added benefits of a necessary process, but it is debatable whether electrification is the most feasible or the best solution to the destruction of trees in rural areas. Firstly, the electrification of rural areas will take time - probably not less than twenty years (Stavrou, 1992:4). What are communities already faced by energy crises to do in the interim? Short to medium term measures to save energy and re-establish biomass supplies are needed (section 7.1.1(b). Secondly, extending the grid is expensive. The poorest households are unlikely to be able to afford electricity even when it is accessible. If the government were to subsidise rural electrification and the cost of electricity, areas such as housing, primary health care or education may suffer. It is possible that these areas of social expenditure may yield greater overall benefits than electrification, in which case they should enjoy priority. Thirdly, the environmental benefits of supplying electricity to rural areas are probably less than those associated with agroforestry, woodlots and afforestation. These measures do not only alleviate pressure on the environment, but aim to restore it and create a basis for sustainable rural living.

The negative environmental impacts of the actual domestic consumption of electricity are not immediately apparent, but are still important.

(iii) *Increase in nett energy consumption* Electricity lends itself to consumption: it is convenient, clean, versatile, nearly always available and cannot be physically handled and measured like other fuels. As a result households with access to it tend to develop energy intensive lifestyles which are reflected in the appliances/products they buy, the consumption of hot water for washing and cleaning, the use of refrigeration, the elaborate preparation of food and the use of lighting - all adding up to an increase in nett energy consumption.

The integrated nature of household and environmental welfare comes to the fore around this issue. Households benefit from using more energy, but each household's consumption contributes to global warming, resource depletion, acid rain and the production of toxic wastes. The problem is further complicated by the disparity that exists between the energy intensive lifestyles of affluent households and the energy scarcity experienced by poor households.

(iv) *Environmental alienation* People reliant on biomass fuels and coal are continually aware of the links between energy use and the environment. By contrast electricity insulates people from the environment because of the way it is delivered and because the negative impacts of generating and transmitting it are not immediately apparent to many people and seldom affect them directly. They therefore become alienated from the environment, not taking any interest in its quality, and not caring or unaware of the effects their energy use has on it. As far as they are concerned electricity is clean and the supply is never ending. Ways of addressing the above two trends are noted in section 7.1.3(d).

5.1.7.2 The transmission of electricity

Once electricity has been generated, it has to be transmitted to where it is needed. Eskom's total network comprises of more than 230 000 kilometres of power lines, operating at voltages as high as 765 kilovolts. Part of this system forms the national grid - about 25 000 kilometres of lines linking all power generating systems in the country (Eskom, 1993:51).

The environmental benefits of the national grid include the efficient use of generating capacity, since power surpluses can be distributed to areas of shortage; the integration of cheap hydro electricity from surrounding countries - Namibia, Lesotho and Mozambique at present, with the possibility of Zaire in the future; that it provides a cheap and efficient means of transferring energy; and that it protects or insulates many consumers from the immediate environmental impacts of generation.

The negative impacts of power lines relate to:

(i) *Construction and maintenance* The effects vary according to the terrain, the type of line, the pylon's design and the construction methods used. The main impact is the clearing of the 'right of way' servitude for the power line and the establishment of access roads. In South Africa there are more than 140 000 km of lines with servitudes varying from 18 to 80 meters. These interfere with normal land use - especially forestry, irrigated agriculture and urban development - and disrupt wilderness areas, particularly where woodland or forest is cleared or where access roads across wetlands are built (Gandar, 1985:64). The lines and pylons themselves pose a threat to birds where they are located across flight paths. In various areas markers are used to warn birds - not so much to save them as to avoid the expense of the power being tripped when they hit the line.

(ii) *Health and hazard effects* Evidence on whether the electric and magnetic fields surrounding power lines pose a health risk is inconclusive; they may increase the risk of cancer very slightly, or they may have no effect. Scientific opinion is divided. If there are any adverse health effects they are probably almost insignificant, otherwise why the difficulty in identifying them? Nevertheless, it may still be prudent to adopt some measures to modify people's exposure to these fields in case new evidence indicates that the risk is in fact greater than thought (Florig, 1992:7; Miller, 1982:401 and 409).

Power lines are, however, a real hazard since accidental contact is usually fatal. These risks are well recognised and measures such as minimum clearances between the conductors and the ground, and vigorous maintenance programmes aim to reduce them (Miller, 1982:401; Eskom, 1992:34).

(iii) *Aesthetic effects* Power lines reduce the aesthetic value of scenic views, interfere with the appreciation of wilderness areas and impair the amenity of residential areas. In more affluent business districts and residential areas underground cables are used, which reduces both the aesthetic impact and the risk posed by power lines.

Section 7.1.4(a)(ii) looks at various ways of limiting these impacts.

5.1.7.3 Generation of electricity

The demand for electricity is the principal cause of the environmental impacts associated with its generation. Domestic demand accounts for 15% of the 149 000 gigawatt hours of electricity distributed in South Africa (Eberhard and Trollip, 1992:19 and 26). Consequently, roughly one seventh of the environmental impacts of generating electricity may be attributed to households.

The nature of the impacts are primarily determined by the energy source used for generation. In 1992 Eskom distributed 98% of the electricity in South Africa, of which 92% was generated from coal, 6% from nuclear power and less than 1.5% from pumped storage/hydro power (Eskom, 1993:48). The environmental impacts of using these different energy sources are looked at below. The aim is to give an overview of the issues and trends.

(a) *Coal generation of electricity*

The environmental impacts of using coal to generate electricity are affected, *inter alia*, by the design and operating efficiency of the power stations; the pattern and quantity of electricity demand; the energy, sulphur, ash, etc. content of the coal used; the location of stations with regard to energy sources, consumers, population centres, local climate and the environment; and, most importantly, the technology used to control stations' waste streams. The social framework in which the generating utility operates is also relevant. Important variables include: public awareness and militancy regarding environmental issues; the utility's commitment to acting responsibly towards the environment; the legal framework protecting the environment - particularly emissions standards, monitoring and compliance requirements, as well as the sanctions for non-compliance; and, lastly, the level of research funding and effort devoted to improving the efficiency of generation and pollution control, as well as the development of alternative energy sources.

As already noted, over 90% of the electricity in South Africa is generated from coal. In 1992 Eskom had seventeen coal-fired power stations, nine of which were in commission, one under construction and two used for stand-by and training purposes respectively. The rest represented excess capacity and had been mothballed. Most of the operational units were very large, having installed ratings of 3600 megawatt and more (Eskom, 1992:22 and 28).

In 1991 Eskom burnt over 70 million tonnes of coal (45% of South Africa's total output) to produce about 135 000 gigawatt hours of electricity. Each main station is located close to a dedicated colliery that has sufficient reserves for its entire working life of forty years or more. This minimises the cost of transport, and means the station is specifically designed to use the coal available. Eskom has developed expertise in the use of coal with a very low energy and high ash content, because it is more abundant and cheaper. In some instances the high grade coal is removed from the coal sent to the power station, and used for other purposes (Eskom, 1992:29 and 36).

Using coal to generate electricity does hold some benefits for the environment. At the general level these include being able to hold a utility responsible for emissions control and environmental rehabilitation, the more effective control of waste streams because the coal is burnt at a small number of localities, and the more efficient transfer/distribution of energy. Benefits may also occur at the station level depending on the technology used both to generate electricity and to control emissions, the efficiency and reliability of operation and the stations' locality. At the household level the benefits include a reduction in indoor and neighbourhood pollution and the more efficient use of energy when the coal is used to generate electricity and not used directly by households.

The negative environmental impacts include:

(i) *Air pollution* Burning coal in power stations reduces the quality of air and, hence, its capacity to deliver many of the environmental services mentioned previously. The extent of the impact is related to three factors: the type and quantity of emissions; the characteristics of the air mass into which they are emitted; and the demographic and biophysical features of the area where they are deposited.

With regard to the last two factors, the situation on the Mpumalanga Highveld deserves special attention. This area of 30 000 square kilometres east of the Gauteng urban complex is the power house of South Africa with eleven power stations (73% of Eskom's total coal-fired generating capacity) located there. Consequently, emissions are concentrated in a relatively small area. The situation is aggravated by the area's climatology which Tyson *et al.* (1988:2) describe as being characterised by climatic conditions which are highly adverse for the dispersion of atmospheric pollutants, namely, high atmospheric stability, clear skies and low wind speeds generally associated with a high pressure system prevailing over the region. During winter, inversions of temperatures occur almost every night at the surface, while elevated inversions occur with high frequency - conditions conducive to the accumulation of atmospheric pollution.

Tyson *et al.* (1988:69) also emphasise that "the natural resources of the area are vital to the economy". Over 50% of the country's high-potential agricultural land and forestry resources are concentrated in the area and along its immediate periphery, up to 25% of the country's water resources come from rivers draining it and adjacent areas, and important conservation areas are located close by.

Eskom is always at pains to point out that electricity generation is not the only polluting activity on the Mpumalanga Highveld (Eskom, 1992:52). This is true, but it is, nevertheless, responsible for 80-90% of the emissions in the area (Tyson *et al.*, 1988:40).

Attention is next given to the environmental impacts of the main air pollutants emitted by coal-fired power stations. Most of the data relates to conditions on the Mpumalanga Highveld.

Particulates: In 1984 it was estimated that power stations on the Mpumalanga Highveld emitted over 300 000 tonnes of particulates per year. Since then the situation has changed due to the commissioning of new stations and mothballing of old ones, the installation of control equipment and an increase in Eskom's coal consumption. Whether the change has been for the better is not known because more recent data are not available.

Eskom has stated that the reduction of particulate emissions is a priority within the organisation: in 1992 R215 million or 6% of its net capital expenditure was spent on upgrading control equipment (Eskom, 1993:21). At present the older stations have precipitators that trap up to 98% of the particulates in flue gasses, while three of the new stations are fitted with equipment that is 99,5% efficient. This still means that a 3600 megawatt power station emits some 12 000 tonnes of particulates per year (Gandar, 1985:61). Greater efficiency is only really possible with bag/fabric filters. Plans are afoot to install such filters in three units at the Duvha and Matimba power stations. To complement these controls Eskom is implementing a policy that will take units which do not comply with legal emission standards for particulates out of service until compliance is achieved (Eskom, 1993:21).

The ambient concentration of fine particulate mass on the Mpumalanga Highveld was measured at less than 20 micrograms per cubic metre, which is almost five times less than in Soweto and well below the guideline of 150 micrograms per cubic metre set by the Department of Health (Lennon and Turner, 1991:2). No corroborating data or time series data could be found. There is also no data on the composition of the particulates available. A number of toxic, carcinogenic and radioactive trace elements found in coal appear to concentrate in the smaller particles which are not as easily collected as larger ones.

At the macro level particulates contribute to global warming since they absorb incident solar radiation (Gandar, 1985:61). The particulates may also act as catalysts in the conversion of other pollutants into more or less harmful forms (American Chemical Society, 1978:161). At the intermediate level particulate depositions/fall out may lead to the accumulation of toxic or radioactive trace elements in the soil, which may cause damage to crops and plantations. However, clear evidence of such impacts have not yet been found on the Mpumalanga Highveld (Vohra, 1982:86; Tyson *et al.*, 1988:91-92). Another impact at this level includes the loss of amenity, i.e. the impairment of clean morning air, clear blue skies or scenic views. The micro level impacts relate to health. Particulates may aggravate asthma and other respiratory symptoms, and increase coughing and chest discomfort. Tyson *et al.* (1988:71) refer to studies that indicate that chronic health effects are not likely to be reliably detected at the ambient concentrations presently experienced on the Mpumalanga Highveld. But this does not discount their occurrence, nor does it take into account the potential effects of long term exposure to low doses of the trace elements found in the smoke.

Sulphur dioxide: In 1987 sulphur dioxide emissions from the generation of electricity in South Africa were estimated to be 1,75 million tonnes per year, with about 70% thereof concentrated on the Mpumalanga Highveld (Tyson *et al.*, 1988:44). Comparisons based on emissions per square kilometre per year suggest that the Mpumalanga Highveld has among the highest sulphur dioxide emission densities in the world (Tyson *et al.*, 1988:44; Clarke, 1991:144). Lennon and Turner (1991:1), in an effort to discredit the unfavcurable impression such compa[illegible] contend that they are "subjective" and not "based upon scientifically [illegible]s". However, irrespective of which comparisons are used, very large [illegible] sulphur dioxide are being emitted uncontrolled into the environment of the [illegible]ga Highveld.

Eskom's policy with regard to sulphur dioxide and other gaseous emissions is to send them "somewhere else, instead of trying to reduce them" (Gandar, 1991:99). Stacks up to 280 metres high lift emissions above the lower inversion layer found in the

Mpumalanga Highveld. The aim is (i) to limit low level pollution and (ii) to allow emissions to be diluted and dispersed in the clean air of the upper atmosphere. With regard to (i) it would appear that the policy has been quite successful so far. Ambient concentration of low-level sulphur dioxide have been measured at 10 parts per billion, which is well within the guideline limit of 30 parts per billion (Lennon and Turner, 1991:2). As regards (ii) the situation is more complex. To start with, Tyson *et al.* (1988:32-34) emphasise that "conditions for the dispersal of plumes over the Mpumalanga Highveld are highly adverse". Plumes even from the highest stacks are not able to penetrate the subsidence inversion layer at about 1 300 metres and so the emissions, instead of dispersing, accumulate in a quasi stable layer of pollution at high level (Tyson *et al.*, 1988:34, 56 and 60). The pollution trapped in this layer poses a significant threat to the environment both within the Mpumalanga Highveld and in adjacent regions due to periodic washouts and the banking thereof against forested mountain areas. So high-stacks may well have transformed what was essentially a local problem to one of regional consequence (Tyson *et al.*, 1988:56, 63 and 67).

Environmental damage from sulphur dioxide emissions on the scale observed in other parts of the world have fortunately not yet occurred in South Africa. This, however, is no reason for complacency. Ambient levels of sulphur dioxide in the vicinity of power stations are at least episodically sufficient to cause damage, and rainfall acidity levels and sulphate deposition rates are enhanced throughout the Mpumalanga Highveld and many of the adjacent areas. The potential for extensive damage, therefore, exists. Until very recently there was a reluctance to delve too deeply into these issues, and even now most of the research is being conducted by Eskom, which raises questions about its objectivity. In the late 1980's plantations east of Belfast in Mpumalanga began to show signs of damage from acidic mists. There is also evidence that the soils in the region are becoming increasingly acidic and so are the streams (Tyson *et al.*, 1988:84). It would appear that "surface soils are buffering the acid input at this stage", thus protecting the streams to a large extent. How long this buffering effect will last is not known (Bosman, 1990:8).

The micro level impacts of sulphur dioxide emissions include damage to physical structures and to people's health (section 5.1.4(i)).

Carbon dioxide: This gas is a pollutant in so far as it contributes to the process of global warming. South Africa's man-made output of carbon dioxide amounts to about 300 million tonnes per year, a third of which is generated by Eskom on behalf of the consumers of electricity (Lennon and Turner, 1991:2; Tyson *et al.*, 1988:40).

In global terms this amount appears insignificant - South Africa's total emissions represent just 1.6% of the global output (Clarke, 1991:154). This impression, South Africa's developing country status, and continued uncertainty about the impacts of global warming have prompted Eskom to adopt a wait and see policy: simply taking 'cognisance' of research developments and not making any commitment to reduce its emissions. Indeed, rudimentary calculations suggest that Eskom's total carbon dioxide emissions have been increasing by about 2% per year since 1984. This approximates the increase in coal consumption. On the positive side, Eskom (1993:21) notes that increasing thermal efficiency has produced a marginal decline in carbon dioxide emissions per megawatt hour sent out.

The principle 'small impacts add up' applies to the production and control of carbon dioxide emissions and, hence, to efforts to avert global warming. The potential for reducing carbon dioxide emissions arising from domestic energy use in South Africa is discussed in section 5.2.

Other emissions: The combustion of coal also generates significant amounts of nitrogen oxides, ozone and aerosols. Low-level ambient concentrations of these substances in the Mpumalanga Highveld are below the guideline limits, although episodic incidents of high ozone concentrations do occur (Tyson *et al.*, 1988:53 54). As in the case of sulphur dioxide, enhanced concentrations of sulphate and nitrate aerosols are found in the high-level pollution layer above the Mpumalanga Highveld.

The environmental impacts of these substances are similar to those of sulphur dioxide, i.e. damage to plants, soil and water sources, as well as buildings and people's health. There is also the added risk that a mixture of these different pollutants may produce synergistic (greater than additive) impacts (American Chemical Society, 1978:165).

(ii) *Water pollution* In 1989 Eskom's coal-fired stations used 260 000 megalitres of water for cooling and washing (Eskom, 1990:4). The scarcity of water in South Africa has led Eskom to develop and install dry cooling technology at three of its largest power stations. These now use only 0.6 litres per kilowatt hour of electricity generated, whereas conventional liquid cooled power stations use 2.5 litres of water (Gandar, 1985:61). In addition, Eskom has a zero effluent discharge policy, so while 80% of the water used in a power station is lost through evaporation, none is discharged. Water introduced into power stations is recycled in a "closed circuit" water system; special measures are taken to keep used water separate from clean water. This negates the problem of thermal pollution and reduces the risk of polluting ground and surface water resources (Eskom, 1992:33 and 36). Leaching from unburied ash heaps is nevertheless a problem.

(iii) *Solid wastes.* The coal burnt by Eskom has a high ash content - averaging about 25%, but going up to 40% in the case of Lethaba (Gandar, 1985:61; Eskom, 1992:26). As a result, Eskom has about 18 million tonnes of ash to dispose of each year. The ash is shallow-buried near the power station: half a metre of topsoil is removed, the ash dumped and the topsoil replaced. The area is then revegetated. Over the forty year life of a large power station up to 800 hectares may be disturbed in this way. Gandar (1985:59) suggests that both the ash and coal discards should be incorporated into the mine infill.

(iv) *Coal mining* At most of the collieries dedicated to Eskom's power stations, open-cast mining is practised. The environmental impacts of this form of mining include localised disruption of ground/soil structure and of ground water hydrology, dust pollution, smoke pollution from discards and the various health risks usually associated with coal mining.

Rehabilitation of mined out areas aims to restore the original topography and potential of the land. Most efforts are fairly successful, although wetlands tend to disappear due to the disruption of drainage patterns. The cost of rehabilitation invariably exceeds the resulting market value of the land, but is many times less than the benefit derived from using the coal. It should, therefore, be regarded as a necessary and legitimate cost of extracting coal. In effect, rehabilitation internalises some of the environmental costs of mining coal.

(v) *Non-renewable resource* Electricity generation uses almost half of South Africa's total coal output, and is, therefore, the most important determinant of the rate at which coal reserves are depleted. Allowing for a moderate growth in demand and using existing technology, domestic coal reserves are probably sufficient to supply local needs well into the 21st century. The high ash content of most of the coal also means that it is best used to generate electricity (Doppegieter *et al.*, 1992:3-11). Whether it is wise to consume coal as rapidly as at present depends on the opportunity cost of foregoing consumption in the future. Since the predominant tendency is to undervalue the future, it may be sensible to depress coal consumption (conserve coal stocks) by increasing its price with a carbon tax. The principal aim of the carbon tax should, however, continue to be the internalisation of the pollution costs of using coal, rather than the prolongation of the carbon cycle energy system. A carbon tax may also encourage the development and dissemination of renewable energy systems by reducing the price differential between these systems and the carbon cycle energy system.

(b) ***Nuclear generation of electricity***

An immense amount of information on the environmental impacts of nuclear energy exists, and yet, vast areas of uncertainty persist.

In 1992 nuclear energy was used to generate 9288 gigawatt or 6% of South Africa's electricity (Eskom, 1993:50). The single station, Koeberg - situated 30 km north of Cape Town - has two pressurised water reactors (PWR) based on French technology with a total nominal capacity of 1930 megawatt. It was built largely for 'strategic' purposes rather than economic reasons and has been in operation since 1984 (Eberhard and Trollip, 1992:27). Eskom (1992:29) claims that it is "inevitable that [it] will have to extend its nuclear capability in future" and has secured "suitable coastal sites" already.

One's assessment of the environmental impacts of nuclear energy depends on how one regards the impacts and risks of radiation. Are the risks controllable and the impacts minimal, or at least no greater than any other industry? If so, then nuclear energy is an attractive alternative to fossil fuels; as Blix (1990:105) points out: "nuclear reactors emit no sulphur dioxide, no nitrogen oxides and no carbon dioxide and ... the wastes they do give rise to are minuscule in volume." Nuclear power is also being heralded as the solution to global warming. Weinberg (1990:101), Blix (1990:109) and many others assert that expanded use of it is imperative if carbon dioxide emissions are to be reduced. Some 5 000 nuclear stations would be required to reduce global carbon dioxide emissions to an "allowable greenhouse budget" by the year 2040 (Weinberg, 1990:102).

The main objections to nuclear power relate to the risk of nuclear weapons proliferation, safety, waste disposal and the lack of public accountability/secrecy which pervades the industry. The first and last points are of a socio-political nature, but they still affect the environment, albeit indirectly.

(i) *Proliferation* Expanded commercial use of nuclear power increases the risk of terrorists obtaining material needed to produce a nuclear explosive device. Security arrangements make it more difficult to divert fissionable material to such groups. However, Ward (1988:29) argues that no amount of security is proof against an "inside job" carried out by an "educated terrorist" of the Baader-Meinhof-type. The existence of a nuclear industry will also bring with it the hazards of trade in nuclear materials. Nuclear smuggling is already taking place, with over 100 reported cases in 1992 (*The Economist*, 1993:86).

(ii) *Safety* In order to assess the safety of nuclear power, the health and environmental consequences of the entire uranium/plutonium cycle should be compared to other energy cycles (Blix, 1990:110). However, the results of any such comparison will tend to depend on who does it and on how widely they interpret 'moral responsibility' in relation to the risks of nuclear power.

Regarding the safety of nuclear power, concern is focused on three areas of risk (in addition to the risk of proliferation): firstly, what are the chances of a serious nuclear accident, and what are the likely consequences? Estimates of the probability of a worst possible accident occurring at a plant such as Koeberg cluster around the 1 in 10 million mark, but as Gander (1985:66) notes, computer modelling of such risks does not ensure any degree of precision, since "accidents are usually caused by the unpredictable." Predicting the consequences of nuclear accidents is no less uncertain: the International Atomic Energy Agency (IAEA) describes Chernobyl as an "extremely costly industrial accident" but maintains that the effects of radioactive fall-out are minimal because "the number of cancer cases from other causes ... is so high that a small addition will hardly be discernible" (Blix, 1990:110). By contrast, Lenssen (1992:49) reports that "estimates predict anything from 14 000 to 475 500 cancer deaths world-wide from Chernobyl." The death toll of a worst possible disaster at Koeberg has been put at 6 000 by Eskom (Gandar, 1985:66). This, however, does not take into account cumulative cancer deaths, genetic effects or the disruption that creating a restricted zone of say 100 kilometres radius around the plant would cause. It would include the entire Cape/Boland area.

Secondly, what risks do low levels of radiation emanating from nuclear facilities pose? Again estimates differ widely because there is disagreement on (i) the effects of radiation and (ii) the industry's ability to contain radiation. With regard to (i), radiological protection standards world-wide are based upon the recommendations of the International Commission of Radiological Protection (ICRP). However, its recommendations have been continually contested on the grounds that they underestimate the effects of radiation. For instance, a re-evaluation of the Japanese atomic bomb survivors showed that radiation is more dangerous than previously thought, but the ICRP (in 1989) refused to act on the evidence (Green, 1989:72-73). The existence of leukaemia clusters among children living in the vicinity of nuclear facilities in the United Kingdom also raises questions about previous assessments of the risks of radiation. The links are still uncertain, but Green (1989:73-74) argues there is sufficient circumstantial evidence to justify concern. Radiation may also damage genetic material causing aberrations in successive generations (American Chemical Society, 1978:436). The extent of such effects will only become evident with time, but the risks are real. As regards (ii) - the industry's ability to contain radiation, the nuclear industry claims to have the technical ability to isolate radioactive material from the biosphere. However, accidents occur. According to Eskom (1993:22) a review of nuclear safety at Koeberg conducted by the World Association of Nuclear Operators found that the station has "good safety practices". However, given the likely of public reaction to negative publicity, Eskom is probably inclined to only publicise 'good news' about its nuclear programme. In addition, the IAEA's failure to uncover the governments' massive bomb making project raises questions about the capacity of outside bodies to fathom what is happening in the South African nuclear industry (*The Guardian Weekly*, 8 April 1993:12). Secrecy pervades the industry and extends to the reporting of accidents such as the release of 29 kilograms of radioactive uranium into the atmosphere at Pelindaba in December 1992 (*Sunday Times*, 4 April 1993:20).

Thirdly, how safe are the methods of nuclear waste disposal? This question is considered below.

(iii) *Nuclear waste* Low and medium level wastes make up most of the volume of nuclear waste. They include the tailings from mining and milling, all the materials (apparatus, protective clothing, cooling agents, etc.) used to enrich uranium, fabricate fuel and generated during the operating life of a nuclear plant, and finally, the equipment, buildings and grounds of nuclear facilities that remain when plants are decommissioned (Lenssen, 1992:52). Although these materials may not be very radioactive, they still contain substances with exceptionally long half-lives. The medium level wastes from Koeberg are mixed with concrete and set in blocks, while the low level wastes are packaged in steel drums. About 1000 of the latter and 500 of the former are generated each year. These are transported to Vaalputs, which is 100 kilometres south east of Springbok in Namaqualand, where they are buried in 10 metre ditches (*Argus*, 14 November 1986:4).

The Atomic Energy Corporation (AEC) claims that Vaalputs is an ideal waste disposal site. Nevertheless leakages from similar disposal trenches have been recorded in the USA (American Chemical Society, 1978:420). This possibility has caused concern, since Vaalputs is situated close to a number of villages whose inhabitants and livestock rely on borehole water (Fig, 1992:123).

High level wastes refer to irradiated fuel and the materials that remain after reprocessing. High level wastes are relatively small in volume, but they are extremely radioactive and extremely long lasting. Safe disposal requires that they are completely isolated from the biosphere for between 600 and several hundred thousand years (if materials that emit highly toxic alpha particles are present) to allow them to decay to innocuous levels. No acceptable means of ensuring such isolation has been devised as yet. At present hopes are pinned on the viability of deep geological burial, but, so far, investigations into possible sites have shown this option to be fraught with uncertainties about the stability of geological formations over periods in excess of half a million years.

Koeberg generates about two cubic metres of high level waste per year which is presently being stored in water at the station, while the short-lived isotopes decay. There are then two possibilities: (i) the waste may be sent overseas, probably to France, for reprocessing, or (ii) it may be dry-stored at Vaalputs in an air conditioned barn (*Citizen*, 14 November 1986:3). The former option would add to the surpl is of plutonium that exists due to disarmament and for which there is no economic use - let alone one that can be justified on ethical grounds (*The Economist*, 1993:88). After reprocessing the plutonium, uranium and remaining high level waste would be returned to South Africa. Shipping waste around in this way is highly undesirable, due to the risk of accidents or hi-jacking while in transit. Neither of the above plans are long term solutions. The AEC and Eskom have referred to the possibility of deep geological burial, but have, as yet, not proposed any acceptable plans for the long term storage of high level waste (Gandar, 1985:66; Eberhard and Trollip, 1992:27).

High level waste poses not only technical problems, but also ethical problems. Firstly, there is the question of intergenerational equity: by using nuclear energy the present generation is imposing costs on future generations. Expressed differently: Do the short term benefits of nuclear power outweigh the long term social costs that are being imposed on future generations? Secondly, the question of private versus social costs is at issue: do the short term private benefits derived from the nuclear generation of electricity in any way balance the long term social cost of storing the wastes over thousands of years? Thirdly, does the present generation have the right to undertake activities that may pose a real risk to the existence of future generations?

(d) *Secrecy* Critics of nuclear power argue that probably the most disturbing feature of it is the ethos of the industry: "the degree of centralisation of power, the secrecy, the restriction of information, the belief in - the almost worship of - technology ..." (Gandar, 1991:111). Undoubtedly a certain degree of secrecy is imperative for security, but where are the limits? The release of 29 kilograms of radioactive uranium at Pelindaba is a case in point. Full details of the incident were only supplied after the issue was raised by the Democratic Party in parliament - five months after it happened (*Sunday Times*, 4 April 1993:20). The Nuclear Energy Act should be amended in order to increase accountability and transparency (section 7.1.4(a)(ii).

(c) *Hydro-electric power*

The environmental benefits of generating electricity from hydro-power are that it is a clean, renewable source of energy and the technology is efficient, simple and reliable. Where an hydro-electric scheme is part of a water development project that involves the construction of a dam, the generation of electricity is just one of many other benefits, which may include increased production of food, a reliable water supply, flood control, navigation, recreation and aquaculture. The whole scheme may also be planned to use labour intensive technology during the construction phase, thus providing much needed employment for a number of years (Biswas, 1982:528).

The environmental costs of hydro-electricity are largely dependent on whether a dam is part of the scheme, and whether it is part of an overall water-development project. Where no dam is needed, as at the Ruacana Falls in Namibia, the environmental impacts tend to be restricted to the disruption caused during construction. Where a dam is built, but hydro-electricity is only a part of the overall project, then it is difficult to attribute the environmental costs of the dam to the development of the hydro-potential *per se*. Instead they should be seen as impacts of the entire scheme. Only where a dam is built solely (or mainly) for the purpose of tapping its hydro-potential are the environmental impacts thereof directly attributable to the generation of electricity. Irrespective of the main purpose of constructing a dam, the negative environmental impacts may be divided into short term and longer term ones. The short term impacts occur during the construction and filling of the dam. They include the environmental disruption at the actual dam site and the boom-town accommodating the workers, and the loss of farmland, forests, wildlife and habitats when the reservoir fills (Biswas, 1982:530; Doppegieter *et al.*, 1992:3-46). The longer term impacts are generally greater than the short terms one. They include:

- the social disruption and loss of welfare caused by the relocation of communities whose homes and land are inundated by the reservoir;
- the introduction of new diseases (bilharzia) or the intensification of existing ones due to improvement of the habitats of the disease carriers - especially in tropical areas (Biswas, 1982:531-535);
- the alteration of aquatic and riparian habitats, as well as farming conditions downstream of the dam due to changes in the water's quality, temperature and flow patterns; and
- the risk of the dam being breached by sabotage, due to a structural weakness or a reservoir-induced seismic shock.

Hydro-potential in South Africa is limited by the lack of suitable sites and the unreliable flow patterns of most rivers. The two hydro-electric power stations on the two largest Orange River dams have a nominal capacity of 540 megawatt. Use is restricted to peaking and emergencies and the availability of water in the dams (Eskom, 1993:50). The use of pumped storage schemes has extended the use of hydro-power significantly. Eskom has two such schemes, one near Bergville, the other near Grabouw with a combined nominal capacity of 1400 megawatt. The Cape Town Municipality also operates a 90 megawatt system at the Steenbras Dam (Eberhard and Trollip, 1992:27). These schemes pump water up to a reservoir during off-peak periods and then use it to generate cheap electricity for peaking. All South Africa's hydro-power stations, except the Palmiet station at Grabouw, are part of water development schemes, so their impacts on the environment must be regarded in that context.

The hydro-potential in Southern and Central Africa is very large. Only about 4% of it has been developed, while 35% of it is economically viable at present prices (Sims, 1991:777). The site with the most potential (between 80 000 - 100 000 megawatts) is at Inga on the Congo River in Zaïre. Proposals to develop it are already being investigated, but very little attention has been given to the potential environmental impacts of damming the Congo River (Du Plessis, 1992). If the impacts are excessive it would be desirable to limit development to that which is possible without building a dam. Every effort should also be made to ensure that the poor people of the region benefit from the project, especially if development loans are used to finance it. This applies to other hydro-electric projects in the region as well.

(d) *Other means of generating electricity*

In addition to electricity generated from the above three energy sources, small amounts are also generated from gas and solar energy. The use of these energy sources is limited in South Africa because they cannot compete with coal as it is priced at present. Photovoltaics are also a relatively new technology for which a market is only starting to develop.

Eskom operates two gas-turbine power stations with a combined nominal capacity of 342 megawatt. They are used for peaking and emergencies and are, therefore, used for only a few hours each year (Eskom, 1993:50). The presence of natural gas off the Southern Cape coast raises the possibility of extending this capacity. However, the existence of Mossgas limits the viability of such a power station, given that to invest more capital in utilising these gas fields would probably be a waste. Nevertheless, such a development would be less environmentally damaging than expanding either the country's coal or nuclear generating capacity, since gas is cleaner and more efficient than coal and does not produce radioactive wastes, (Bennet *et al.*, 1992:116). It would also be in line with the suggestion that gas be used as a low pollution 'bridge' to a more sustainable energy system (Flavin, 1992:41-43). In addition a gas powered station could also utilise biogas (Rivett-Carnac, 1982:110).

In South Africa solar energy/photovoltaic installations for generating electricity have an estimated capacity of 3 megawatt. The few households with such installations are mostly situated in areas that are too remote to be economically linked to the national grid (Eberhard and Trollip, 1992:28). Photovoltaic systems have virtually no negative impact on the environment once installed, although there are fairly substantial environmental costs associated with their manufacture.

Other possible energy sources for generating electricity are still only being discussed or researched in South Africa. Renewable sources with potential are wind energy, biogas, municipal waste and wave energy along the Natal South coast (Doppegieter *et al.*, 1992:3-51; Eberhard and Trollip, 1992:33). The potential of using solar energy to supply grid electricity also deserves mention.

5.2 Environmental impacts of energy conservation

The aim of energy conservation is to increase the efficiency with which present energy services are delivered, as well as to curtail certain uses of energy (Brown and Shaw, 1982:39). Since conservation tempers the demand for primary energy, the savings may be regarded as an additional energy 'resource'. This resource is 'found' in all sectors of the economy - wherever energy savings or improvements in energy use efficiency are possible. In this section the focus is on energy conservation in the domestic sector; more specifically on the impact that this has on the environment.

Section 7.2 goes one step further and looks at what government and households can actually do in order to conserve energy, as well as the contribution alternate energy sources can make.

Energy conservation at the macro level is measured in terms of the ratio of energy consumption to economic output - E/GNP; also referred to as the energy intensity of the economy. Gerholm (1992:27) is critical of this measure because the E/GNP ratio "can also be reduced by economic measures that raise productivity" without energy being used more efficiently. As it is, this measure is of little use in the domestic sector, since it is difficult to value household activities. Energy savings in the domestic sector are, therefore, measured as a percent of pre-conservation energy use of the specific household or of a sample of households not conserving energy (Nadel, 1992:508-509).

Factors that influence energy conservation's effect on the environment include:

- the quantity of energy saved;
- the type of fuel/energy source (saving fossil fuels usually yields greater benefits than saving energy from renewable resources);
- the conservation measures/policies used;
- climate (savings in cold regions tend to be greater than in warmer regions because more energy is used for space warming in the former); and
- the extent of non-environmental benefits or costs of energy conservation.

Less obvious, but more important, is the role that attitudes and perceptions play. If there is little appreciation for the environment and the services it renders, or if energy supplies are perceived as abundant and cheap, then conserving energy is unlikely to be considered worth pursuing (Williams, 1987:6).

Table 5.1 below gives an indication of the potential for energy conservation and, hence, the possible extent of environmental impacts. The low, likely and high estimates are not based on the same sets of variables, since they are taken from various sources that used different models to calculate the values. The table only indicates possible orders of magnitude. Unfortunately, only a few estimates based on South African data could be found, but, as Williams (1987:12) notes, estimates from elsewhere in the world leave no doubt of the "potential for substantial energy savings ... in this country".

Table 5.1: The potential for energy conservation

Energy source (sector/appliance)	Technical conservation potential (%)		
	Low	Likely	High
Electricity (all sectors)	9[1]	25 - 30[1]	70[1]
Coal (coal stove)	-	-	33 - 50[2]
Fuelwood (wood stove)	19[3]	30[2]	60[3]

Sources: 1. Nadel, 1992:511
2. Lennon and Turner, 1991:8
3. Karekezi, 1990:1-23

The micro level environmental benefits of conserving biomass fuels and coal tend to accrue directly to the households making the saving. Conserving these energy sources reduces the emissions from combustion. The main conservation measure - an efficient stove - also usually removes smoke from inside the dwelling. The combined result is a reduction in indoor pollution or, conversely, an improvement in indoor air quality which reduces the risk to people's health and enhances amenity. Similar, but less pronounced benefits may also accrue from conserving paraffin or gas. No such direct benefits arise when households conserve electricity.

Micro level benefits also occur at those points where energy resources are taken from the environment and where electricity generation takes place. When less fuelwood or coal is consumed, fewer trees are cut down and less coal mined, thus preserving these resources as well as the micro habitats that would be disturbed by mobilising them. Conserving electricity would also reduce the amount of coal mined and the problems of local pollution around power stations. Over a number of years such savings add up.

The intermediate level environmental benefits of households conserving energy still tend to be geographically confined, but affect the households saving the energy less directly. This is particularly so in the case of conserving fuelwood, i.e. the households saving fuelwood do not derive much direct benefit from their action, since the main benefit would be less pressure on tree stocks which is a rather intangible benefit from the household perspective. However, at the intermediate level it can be significant, especially in the former homeland areas. Table 5.2 indicates the potential extent of benefits if savings in fuelwood reached the indicated levels by the year 2000.

Table 5.2: The potential benefits of conserving fuelwood in the year 2000

% uptake of conservation measure	Fuelwood consumption (tonnes per year)			Number of trees[1] saved per year		
	0% saving	25% saving	50% saving	0% saving	25% saving	50% saving
0% uptake	8 305 300	8 305 300	8 305 300	0	0	0
25% uptake	8 305 300	7 786 200	7 267 100	0	4 152 700	8 305 300
50% uptake	8 305 300	7 267 100	6 229 000	0	8 305 300	16 610 600
75% uptake	8 305 300	6 748 100	5 190 800	0	12 458 000	24 915 900

Source: Aron *et al.*, 1989:10
Note: 1. 125 kg assumed to equal one tree

Obviously, the potential for saving fuelwood varies between regions. In the former homeland area of Qwa Qwa, for instance, 80% of the population lives in peri-urban and urban areas where total fuel use is already constrained. Therefore, the potential for savings is also limited. By contrast, in the former Transkei over 80% of the population lives in rural areas, where per capita consumption of fuelwood is about 650 kilograms per year (Aron *et al.*, 1989:9). Consequently, greater savings are possible. If any of the above levels of saving were to be achieved the impact would be significant and even more so if maintained over ten years or longer. Not only would tree stocks benefit greatly, but also the broader environment, since, as already noted, trees provide habitats for animals and plants, promote water retention, prevent erosion, absorb carbon dioxide and moderate local climates (sections 5.1.1 and 7.1.1(b)).

Conserving fuelwood and coal would ameliorate the problem of intermediate level/urban air pollution, especially in black residential areas. Lennon and Turner (1991:8) present data that indicates that using wood and coal stoves for cooking and space heating would increase energy-use efficiency by a third and reduce emissions by a third. Such measures would reduce health risks and improve the amenity of the environment in the areas where they are implemented.

Probably the most significant intermediate level benefit of conserving electricity is that it reduces the demand for increased generating capacity. Between 1982 and 1992, peak demand for electricity increased at 3% per year (Eskom, 1990:5; Eskom, 1993:48). If conserving energy could reduce this rate of growth to 2% per year over the next decade, only 4500 megawatt would have to be brought into commission, instead of 6800 megawatt. In other words one less power station the size of Koeberg or Hendrina would have to be built, which means one less power station polluting the air and water, or producing hazardous waste, and occupying land (Nadel, 1992:510; Nasionale Bounavorsinsinstituut, 1977:1). Electricity would have to be conserved in all sectors to achieve such a saving. The crucial question is whether investing in energy conservation is cheaper than investing in new generating capacity. Numerous studies of utilities in the USA indicate that conservation is cost-effective (Ford, 1990:117; Nadel, 1992:509).

The macro level environmental benefits arising from households conserving energy affect households only indirectly, since they relate to inter-regional and global problems. Conserving fuelwood reduces pressure on tree stocks, hence it has been identified as a means of counteracting desertification (Davidson and Karekezi, 1992:6 and 10). Table 5.2 suggests what may be achieved. Conservation also brings fuelwood use closer to being a sustainable form of resource utilisation. In the same vein, conservation reduces the consumption of non-renewable resources. A 15% saving in domestic electricity use could reduce Eskom's total annual consumption of coal by 1.6 million tonnes or more than 2%. Even if an absolute reduction in coal consumption is not possible, at least conservation would moderate demand growth.

Since energy conservation reduces or moderates the amount of fuels burnt, it is widely regarded as part of the solution to acid rain and global warming (Nadel, 1992:510; Davidson and Karekezi, 1992:10; Everest, 1989:102). Reducing the combustion of coal and other fuels means that fewer emissions will be produced. This reduces the risk of damage being caused by acid rain and mists, as well as dry depositions of pollutants. Nadel (1992:510) notes that several studies in the USA have shown that demand side management programmes "can be less expensive per ton of sulphur dioxide removed than scrubbers [equipment used to wash emissions]".

The contribution of energy conservation to reducing carbon dioxide emissions could be crucial to averting global warming (Everest, 1989:102). Table 5.3 below gives a rough estimate of the contribution that conserving different amounts of energy in the domestic sector could make to reducing South Africa's carbon dioxide emissions.

Table 5.3: Possible reductions in carbon dioxide emissions from energy conservation in the domestic sector in South Africa

Source of energy saving	Reductions in carbon dioxide emissions (tonnes) at different levels of energy saving			
	10% energy saving	30% energy saving	50% energy saving	30% over ten years
Fuelwood	1 464 200	4 392 600	7 321 000	43 926 000
Coal	976 500	2 929 500	4 882 500	29 295 000
Electricity (coal)	1 510 600	4 531 800	7 553 000	45 318 000
Trees saved	265 800	797 300	1 328 800	7 973 000
Total	**4 217 100**	**12 651 200**	**21 085 300**	**126 512 000**
% of South Africa's total annual CO_2 output	1.4	4.2	7.0	

Sources and notes:
1. In all cases an 80% uptake of energy conservation measures is assumed
2. Aron *et al.*, 1989:10
3. Viljoen, 1990:82
4. Lennon and Turner, 1991:8
5. Eberhard and Trollip, 1992:23
6. Eskom, 1993:22 and 48
7. Clarke, 1991:154

While savings of less than 5% of South Africa's total carbon dioxide emissions may seem small, it is a start, and the cumulative benefits over a number of years would make it all the more important.

Negative environmental impacts of energy conservation are few, being almost entirely restricted to the impacts associated with the use of materials and energy in the implementation of conservation measures. A more critical question is: does energy conservation reduce energy demand? In so far as it refers to increasing energy-use efficiency, Gerholm (1992:25) argues "no" and quotes Jevons (1865):

> ... it is wholly a confusion of ideas to suppose that the economical use of fuel is equivalent to diminished consumption. The very contrary is the truth ... . It is the very economy of its use, which leads to extensive consumption.

Restated, their argument is that the efficient use of energy makes it more competitive vis-à-vis other production factors. Hence, energy will, to some extent, substitute for these factors, thus causing energy demand to increase. But the substitution process is constrained by technology and the extent to which the demand for energy services has already been satisfied. If technology is constant, then at some threshold level of energy use the opportunities for continued substitution will decline and further increases in efficiency would lead to energy savings without affecting the delivery or quality of energy services. So whether energy conservation will reduce energy demand is partly dependent on the relative strengths of the substitution effect and the impact of increasing efficiency. The second leg of energy conservation, namely, curtailing excessive, wasteful uses of energy will definitely reduce the demand for energy. Evidence from utilities in the USA and Europe, as well as from stove projects in developing countries, indicates that energy conservation programmes do reduce overall energy demand (Nadel, 1992:521; Ford, 1990:117; Karekezi, 1990:1-23).

Ways of reducing energy consumption and conserving energy in general are discussed in section 7.2.

5.3 Environmental impacts and the domestic energy transition

The question addressed in this section is the following: How do the environmental impacts of household energy use change as they progress through the different phases of the domestic energy transition process? In other words, what environmental benefits, if any, accrue when households move from using, say, fuelwood to using paraffin, etc.? The aim of the analysis is to provide information on which patterns of energy use are preferable from an environmental perspective. It also draws attention to those patterns of energy use that need to be modified in order to reduce their adverse environmental impacts.

The section uses the standard model presented in section 2.3.3 as a framework for the discussion. Attention is given first to the rural energy transition, then to the changes in the environmental impacts that occur during the urbanisation process, then to the urban energy transition and, lastly, to some overall trends in the nature of the impacts.

5.3.1 Environmental impacts and the rural energy transition

(i) *First rural transition phase* Households in this phase of the energy transition rely almost entirely on fuelwood gathered from adjacent wooded areas for their energy needs. It is usually burnt on an open fire situated either inside the dwelling (often in the centre) or in a cooking shelter. Alternatively, the fireplace may be situated outside, close to the dwelling's entrance. Where the fireplace is situated has a direct bearing on the severity/incidence of indoor pollution.

The most important environmental benefit of the energy use pattern in this first phase is that fuelwood, under normal circumstances, is a renewable and sustainable energy resource. Other environmental benefits include the relative cleanliness of fuelwood emissions and the fact that emissions are spread over a large area and therefore do not overload the environment's waste disposal capacity in any one place. In addition, households in this phase tend not to use excessive amounts of energy, due to the nature of the energy source (lack of versatility) and the need to gather it.

The indoor pollution referred to above is the principal negative consequence. The smoke from cooking fires affects people's health, as well as the amenity of their home environment. The combustion process also releases gasses which aggravate macro environmental problems such as global warming, but these effects are relatively small when compared to the impacts of other energy sources. The use of fuelwood also damages the environment when demand exceeds the regenerative capacity of the tree resource base. The loss of tree cover is, however, usually not a feature of energy use in the first rural transition phase, except maybe towards the very end of it. Then the growing scarcity of fuelwood causes households to change their pattern of energy use and so move forward to the next phase of the energy transition.

(ii) *Second rural transition phase* In this phase household energy use patterns are in a state of flux. The increasing scarcity of fuelwood will, initially, induce the use of dung/crop wastes until incomes rise and distribution networks improve sufficiently for paraffin to become a viable alternative.

The environmental benefits of energy use patterns in this second phase are similar to those noted in the first phase: the biomass fuels are renewable, the emissions, from a macro perspective, are comparatively clean and spread over a large area, and energy is used sparingly. In addition, people in this phase are often sensitive to the environmental problems associated with the scarcity of biomass fuels, especially the impacts of loss of tree stock.

The gradual transition to paraffin which takes place during this phase helps reduce local (especially indoor) pollution which has beneficial effects on people's health and the amenity of the home environment.

Prior to the transition to paraffin, the principal negative impact is the indoor pollution resulting from the use of biomass fuels. Dung/crop wastes aggravate the problem since they combust at low temperatures, i.e. combustion is incomplete leading to the release of large amounts of smoke. The scarcity of energy sources is another factor. In an effort to conserve energy households burn fuels indoors with minimal ventilation. The impact this practice has on people's health can be severe, even fatal if carbon monoxide poisoning occurs.

The increasing scarcity of fuelwood in this phase is evidence of another set of important negative environmental impacts. Population pressure and mismanagement has severely damaged the tree resource base in many areas and wiped it out in some. This has wider biophysical and ecological effects since trees are vitally important to the environment.

The growing scarcity of fuelwood also causes households to start using dung/crop wastes which sets a dangerous cycle of soil impoverishment in motion.

Compared to the first transition phase the impacts in this phase are not only more noticeable, but also more severe. However, many of them are only indirectly linked to the type of energy source. More important are the circumstances under which the fuels are used and the conditions of the environment from which they are obtained. Consideration must be given to these factors when assessing the environmental impacts in this phase.

The changes in pattern of energy use that occur in the second rural transition phase represent the first moves away from renewable and (potentially) sustainable energy resources to non-renewable energy sources. This trend is for all practical purposes irreversible. It represents a fundamental change in households' relationship to the natural environment. In all successive transition phases household energy use patterns become progressively less sustainable and the environmental impacts become more difficult to reverse.

(iii) *Third rural transition phase* Household energy consumption patterns in this phase are fairly stable compared to the previous phase, but also a lot more varied in terms of the fuels used and the quantity consumed by individual households. Most households use a mix of fuels - fuelwood, paraffin and gas; a minority use stand-alone generators and some more wealthy homesteads have access to grid electricity (in areas where it is available). The consequence of this diversity is that households' impact on the environment vary widely in this phase.

This phase is characterised by a transition to energy sources that ameliorate indoor and local pollution. The benefits are greatest when the transition involves a move away from biomass fuels, especially dung/crop wastes. Greater reliance on paraffin, as well as gas and electricity, benefits people's health and improves the amenity of their home environments and helps alleviate some of the negative consequences associated with the use of these fuels.

The benefits arising from emissions being dispersed over a large area apply to most households in this phase.

The principal negative environmental impacts in this phase relate to the changing mix of fuels used. The movement away from biomass energy sources, along with rising incomes, opens the way for households to increase their consumption of energy substantially. Households' impact on the environment is, therefore, greater in this phase relative to the previous phases. The use of coal and paraffin contributes to the depletion of non-renewable resources. The emissions released during the combustion of these fuels also aggravates air pollution problems since they are not as easily neutralised by the environment as those arising from biomass fuels. There is thus a trade-off between the beneficial impact these energy sources have in reducing local pollution effects and the impact they have on macro-environmental problems. The amount of energy households consume also increases thus increasing their overall impact on the environment. Lastly, the new sources of energy households consume insulates them to some extent from the local environment and so reduces their sensitivity towards the environment and environmental problems.

5.3.2 Environmental impacts of energy transition during urbanisation

The effect that the urbanisation process has on the environmental impacts of the energy transition is dependent on which phases in the rural energy transition process the households move out of and which phases in the urban transition process the households join. As noted in section 2.3.3.1, the lines between the rural and urban transition sections of the standard model suggest which urban transition phase a household coming from a specific rural phase is most likely to slot into when moving to an urban area.

At present most rural-urban migration appears to be out of the first and second rural transition phases into the first urban phase. Households making this move obviously have to make great changes in their energy use patterns. Most of them become almost completely reliant on paraffin and coal, since biomass fuels are exceptionally scarce, if not unobtainable, in urban areas. A few households from these early rural phases may be fortunate to be able to get access to housing that is electrified on moving to an urban area. They thus join the second or third phases of the urban transition process. Households moving out of the third rural transition phase are more likely to join the third or later urban transition phases than households moving out of the earlier phases of the rural energy transition. Such a shift would not usually involve a great change in their energy use patterns.

The most important environmental benefit that may arise from urbanisation is that households' exposure to indoor and intermediate pollution may decline, since the scarcity of biomass fuels forces them to use cleaner energy sources. This benefit would be greatest where households get access to electricity. However, where households, on urbanising, begin to use coal, all benefit would be lost and they may in fact experience worse indoor and intermediate pollution, since the proximity of other households leads to emissions being concentrated in small areas.

Where households get access to electricity on urbanising, the impact of the emissions resulting from their use of energy changes from being dispersed to being concentrated around the power stations. There is thus a trade-off between greater local environmental impacts around such stations and virtually no local impacts in or around households where the energy is used.

By urbanising, households inevitably become more dependent on non-renewable energy sources. There is therefore a movement away from potentially sustainable patterns of energy use to ones that are unsustainable, since the environmental impacts of using paraffin, coal, and electricity are more difficult to reverse once they have occurred.

The greater use of non-biomass energy sources in urban areas leads to a decline in household environmental sensitivity. Their direct dependence on the environment is largely hidden by the supply networks of the different commercial energy resources, especially electricity. The link between their pattern of energy use and the resultant effects on the environment is not as obvious as when they collected fuelwood directly from their environs.

Lastly, the movement of households to urban areas lays the foundations for changes in habits and expectations that lead to more energy intensive lifestyles than is the norm in rural areas.

5.3.3 Environmental impacts and the urban energy transition

(i) *First urban transition phase* Two patterns of domestic energy use are found in this phase: in coal producing regions, namely Gauteng, Mpumalanga and parts of KwaZulu-Natal, households use about equal amounts of coal and paraffin, while in other urban areas households are almost totally dependent on paraffin. The nature of the environmental impacts is directly linked to which one of these patterns predominate in an area.

The level of energy consumption in this phase is, on average, lower than in all other phases of the energy transition process, therefore it cannot be regarded as a significant factor in the nature or extent of the environmental impacts that occur.

The main environmental benefits of using paraffin are that it is a cleaner energy source than coal, it replaces biomass energy sources which are very scarce in urban areas and its emissions are spread over a wide area, reducing the risk of intermediate level pollution.

There are few environmental benefits to be had from using coal domestically. Even the fact that the emissions are spread over a large area is not a benefit (as is the case with other fuels), since coal fires emit substantial amounts of pollutants which can be less effectively controlled in homes than at a central point, like a power station.

Where paraffin use predominates, the negative environmental impacts are likely to be relatively mild. The most significant result of households using it without adequate ventilation, thus exposing members to above average levels of pollutants which may impair their health. Other negative impacts of paraffin use include small additions to global air pollution and the problems caused by the petroleum industry and the depletion of a non-renewable resource. Paraffin's detrimental impact is, however, far less than that of coal.

The negative impacts of the domestic use of coal are discussed in detail in section 5.1.4. There it was noted that coal's impacts on the environment are affected by factors ranging from the quality of the coal used to the circumstances under which it is burnt. In most cases the use of coal by households results in serious indoor and neighbourhood air pollution. The level of indoor pollution is sometimes so high that it has debilitating, even fatal, consequences due to carbon monoxide poisoning. Otherwise the enhanced levels of pollution cause and aggravate numerous respiratory conditions. The impacts of neighbourhood pollution include harm to peoples' health, reduced amenity and the corrosion of structures. Other impacts of coal use include pollution caused by the uncontrolled dumping of ash, the depletion of a non-renewable resource, the aggravation of macro air pollution problems and the impacts associated with the mining of coal.

The environmental impacts resulting from the use of coal are greater than the impacts associated with any of the rural transition phases. Indeed the air pollution problems are so serious, especially in townships in Gauteng, that they are one of the factors behind the concerted electrification drive that is under way. It is likely to reduce the neighbourhood effects by transferring the bulk of the problems to the sites of power stations. Thus, a trade-off occurs between increased pollution around power stations and lower pollution in residential areas.

(ii) *Second urban transition phase* This phase is characterised by rapidly changing patterns of energy use. The most important change is the transition to gas and the complementary decline in the dominance of paraffin and coal in household energy budgets. Household consumption of energy also increases across the phase as incomes increase and lifestyles become more energy intensive.

The environmental benefits of the transition to gas are significant. Gas is the cleanest of the hydrocarbons. Its use in the home has no noticeable effects on indoor or neighbourhood environments and it contributes less to global environmental problems than any other carbon fuel. It is also a very efficient fuel. The only drawback is that natural gas is a non-renewable resource.

At the beginning of the phase the environmental impacts of household energy use are similar to those of the previous phase, given that the energy use patterns are similar. The transition to gas, however, means that many of the negative impacts associated with the use of paraffin and, particularly, coal disappear. Unfortunately, gas is mainly used for cooking, while coal is mainly used for space warming. The transition is, therefore, rarely complete.

The overall effect of the changes in this phase will include a reduction in the severe indoor pollution problems noted in the previous phase. The impact on neighbourhood pollution will depend on whether the level of coal consumption declines as a result of the use of gas or persists due to increases in total energy use. The effect on global problems is likely to be greater due to the increase in energy use across the phase.

During this phase households are likely to become less sensitive to environmental problems since they will be progressively more able to shield themselves from them as their income increase and as the environmental effects of their energy use become less obvious than, say, when the use of coal causes visible air pollution.

(iii) *Third urban transition phase* At the beginning of the phase gas is the dominant fuel, but a transition to electricity occurs with the electrification of households. The present emphasis on electrification means this is taking place very rapidly. Households may continue to use gas for cooking for some time afterwards, but given the convenience and the versatility of electricity there is a tendency to use it to perform all energy related tasks. This gives rise to an upward trend in households' total energy consumption across the phase.

At the beginning of this phase the environmental impacts are relatively mild where gas is the dominant energy source. The transition to electricity has only limited environmental benefits in such circumstances. The most obvious is that electricity is totally clean from the household perspective.

The main negative environmental impacts of electrification include: the environmental effects of extending the national grid; the concentration of emissions at a limited number of generation sites; the rapid increase in household total energy consumption that access to electricity facilitates; and a general decline in households' sensibility to environmental problems due to the fact that access to electricity insulates them from most of the impacts of their energy use.

Overall, gas is a cleaner energy source than electricity generated from coal or nuclear power.

(iv) *Fourth urban transition phase* This phase is characterised by the almost total dominance of electricity in household energy budgets. Other energy sources are only used for specialised functions and for back-up. The main trend in this phase is the increase in energy use that occurs as households accumulate appliances and develop progressively more energy intensive lifestyles.

As in the previous phase, the most important benefit is that electricity is a clean energy source from the domestic perspective. This has very important health benefits and raises the amenity of the home environment greatly. Another benefit is that burning coal at a central point such as a power station enables more effective control of the emissions. However, there is still a trade-off between greater local environmental impacts around power stations and the smaller impacts on macro problems such as global warming, and virtually no local impacts in or around households where the energy is used. The importance of this trade-off is, however, limited at present, but will gain in importance as the electrification programme proceeds.

These environmental benefits can, however, not be regarded in isolation. Section 5.1.7 discussed a wide range of negative environmental impacts associated with the generation, transmission and consumption of electricity. The most important of these are: the increase in nett energy consumption that access to electricity facilitates; the environmental impacts of the national grid; the air pollution caused by the coal generation of electricity; the risks of serious environmental disruption in the event of an accident at a nuclear power station; the risks associated with storing highly toxic and radioactive nuclear wastes; and the depletion of non-renewable resources such as coal.

The domestic sector consumes about 15% of the electricity generated in South Africa. Households in this phase are responsible for the bulk of this since their levels of energy use are substantially higher than those of the newly connected households in the previous transition phase. Households in this phase are, therefore, responsible for a greater proportion of the domestic sectors 'share' of the negative impacts associated with the different components of the electricity industry.

The most worrying dimension of energy consumption patterns in this phase is that most households act as if there were a never-ending supply of electricity. Access to electricity insulates people from the natural environment, consequently they become alienated from it and take little interest in its quality and do not care or are unaware of the effects their energy use has on it.

5.3.4 Overall trends

The environmental impacts across the entire energy transition process vary significantly from the initial rural phase to the last urban phase. Indeed, the impacts between any two adjacent stages differ substantially. This should come as no surprise given the complex nature of interactions between the different patterns of energy use and the environment. It is, however, possible to identify some broader trends in the nature of the environmental impacts of energy use across the entire domestic energy transition process.

To start with, the impacts are mainly of local significance in the early rural phases, e.g. indoor pollution, but they become gradually more important from the global perspective as the transition process progresses, e.g. global warming, acid rain and the depletion of non-renewable resources. The impacts also change from being dispersed among individual rural households to being concentrated first in urban areas and then around power stations. Given a constant amount of air pollution, the environment would be able to neutralise it if it were widely dispersed, whereas serious environmental problems result if it is concentrated within a small area. This is what happens on the Mpumalanga Highveld.

The negative environmental impacts of domestic energy use increase and become more complex as the transition process progresses. This is partly due to the fact that household nett energy consumption increases across the process and partly due to the fact that the pollutants from the energy sources used in the later phases of the process are more complex than those used in the early phases. For instance, wood smoke is almost innocuous, while nuclear waste is highly dangerous.

Household patterns of energy use become progressively less sustainable across the transition process. This is principally due to the transition from biomass fuels, which are potentially renewable, to non-renewable energy sources in the second rural phase. However, in many rural areas tree stocks are being depleted because use levels are not sustainable. Therefore, somewhat ironically, the use of non-renewable energy sources helps alleviate the pressure on tree stocks and thus reduces the environmental problems resulting from the unsustainable use of this renewable resource. Another factor making for less sustainable energy use patterns, is the increasing trend in household nett energy consumption across the entire process.

Lastly, the transition from biomass energy sources to commercial fuels and finally to electricity has the effect that households become less and less sensitive to the state of the environment and the link between their pattern of energy use and environmental problems. Indeed, in the fourth urban phase households are so insulated from the impacts they have on the environment that it is possible to speak of environmental alienation.

CHAPTER 6

THE WELFARE IMPACTS OF DOMESTIC ENERGY TRANSITION

Household welfare is determined by the extent to which basic needs and other needs, desires and conditions (the intermediate goals of welfare) are satisfied, as well as by individuals' subjective assessment of their welfare position (section 1.2.1). This chapter examines how domestic energy use affects household welfare at each of these levels and how the domestic energy transition changes the nature of these welfare impacts.

In chapter 4 attention was given to how each of the energy sources impacted upon household welfare in terms of the quantity of energy households derive from them and in terms of their scarcity/availability and their versatility. A number of other aspects relevant to the particular energy sources and household welfare were also noted. This chapter builds onto these points.

The aim of this chapter is to provide a coherent structure for discussing the multidimensional nature of the relationship between energy use and household welfare and to investigate what happens to household welfare in the different phases of the domestic energy transition.

Broadly speaking, the impacts of energy use on household welfare can be divided into two groups: firstly, there are the direct/intended consequences of domestic energy use, e.g. the welfare derived from using energy for cooking, providing warmth, lighting and home entertainment. Secondly, there are impacts that either affect the quality, nature and availability of the above mentioned direct impacts, or affect welfare through other variables such as income and price or attitudes and perceptions. However, this division has only limited value, since all variables that affect welfare also affect each other.

The integrated approach is as relevant in this chapter as in the previous one. In section 1.3.2 it was noted that people/households derive at least four services from the environment, namely: the provision of basic needs, the satisfaction of other needs, the disposal of wastes and amenity services. The focus of this chapter is principally on the first two - provision of basic needs and the satisfaction of other needs/desires - regarded from the perspective of household welfare - whereas the emphasis in chapter 5 was on the impacts that the mobilisation of energy resources and the disposal of wastes generated by the use of energy have on the environment. These may appear to be separate issues, but there is a large degree of overlap, especially in the case of matters such as health and the measures that might be taken to enhance the benefits and moderate the negative impacts of energy use. In addition, it is in using energy to meet their needs/desires that households generate the environmental impacts that were the topic of chapter 5. It cannot be emphasised enough that the welfare of the environment and of households is interdependent. Factors affecting the one also affect the other. In addition, the factors themselves affect each other, e.g. the excessive use of fuelwood depletes tree stocks which harms the natural environment and increases the real cost of fuelwood, since more time is needed to gather it, which affects household welfare.

This chapter is divided as follows: section 6.1 looks at how or to what extent households' basic energy needs are satisfied. Section 6.2 focuses on ways in which the use of energy affects the attainment of other needs/desires or what are referred to by Terreblanche (1986:58) as the intermediate goals of social welfare. How energy use affects the attainment of each of these goals is discussed in sections 6.2.1 to 6.2.4. Section 6.3 examines people's subjective assessments of how energy use affects their welfare position and, lastly, section 6.4 identifies the welfare impacts of domestic energy use associated with the different phases of the standard model (described in section 2.3.3) and analyses overall trends in their occurrence.

As in the previous chapter, this chapter covers a vast amount of ground. As a result the treatment of the different topics is not exhaustive, but directed towards identifying broad trends. In addition, not enough attention could be given to the way variables interact, either reinforcing or lessening each other's impact on household welfare. These interactions are important to understanding what effect changes in energy use patterns resulting from the domestic energy transition process have on household welfare. The subjective indicators may capture them to a limited extent, but this does not preclude the need for them to be studied more completely.

6.1. Basic energy needs

It was noted in section 1.2 that energy is seldom listed as a basic need, but that it is one is indisputable. People use energy to perform numerous tasks; of these the most essential are cooking, heating water, providing warmth and lighting. If people have insufficient energy to perform these tasks they will suffer a form of deprivation, which might be called energy poverty, that is as debilitating as hunger, thirst or exposure.

Section 6.1.1 discusses the nature of energy poverty and, using the poverty lines suggested in section 1.2.1, examines levels of energy poverty in South Africa using data from chapter 4. Section 6.1.2 discusses the distribution of energy use between different essential energy services just noted, namely cooking, heating water, the provision of warmth and lighting.

6.1.1 Identifying energy poverty

A household in a state of energy poverty does not have sufficient energy to meet its basic needs for energy either on average or at a specific time. In other words (i) the household's average level of energy consumption is so low that energy tasks such as cooking, heating water, providing warmth and lighting are generally inadequately performed, and (ii) the household may suffer a shortage of energy at a time when it is essential for survival, e.g. on a very cold night.

These two situations differ from each other quite considerably. The first instance, (i), refers to an energy deficiency which is ongoing or persistent, but not so critical as to be immediately life threatening; households have access to energy, but never enough. Like other forms of poverty it has a gradual, insidious effect on living standards. Only households with very low incomes or in particularly harsh environments usually suffer this form of energy poverty. The second instance, (ii), refers to a state that can befall any household - rich or poor. An unforeseen/accidental break in any households' normal energy supply can have disastrous consequences, especially in very cold weather. Despite these differences, these two dimensions of energy poverty are linked, since the risk of a household suffering a critical energy shortage is far greater if its normal access to energy is inadequate, i.e. households suffering from energy poverty of the first form (i) are more exposed to the second form (ii) of energy poverty as well. In this section the discussion focuses on energy poverty in the first sense: households suffering from persistent, inadequate access to energy.

Energy poverty can be identified by its consequences. These include undercooked meals (which may result in forms of malnutrition); severe indoor pollution caused by households trying to conserve energy by reducing ventilation and/or burning low grade fuels such as dung, crop wastes, cardboard or poor quality coal; the use of unsterilised water; and low indoor temperatures on cold nights due to a lack of space warming. The severity of these consequences is to some degree dependent on factors such as people's staple diets and cooking habits, the quality of their water supply, the altitude, climate and weather and the quality of their housing. The most important factor, however, is obviously their level of energy consumption and the extent to which this falls short of their needs.

Energy poverty lines

The question, what is an adequate level of domestic energy consumption, was touched on in section 1.2.2. There it was noted that poverty lines may be thought of as comprising two elements: an objectively determinable amount of energy that is necessary to sustain life, and a further amount that may be regarded as necessary to participate in everyday life. Two energy poverty lines were suggested:

- 10000 MJ (10 GJ) per capita per year for domestic nett energy consumption; and
- 1500 MJ (1.5 GJ) per capita per year for useful domestic energy consumption.

In section 1.2.2 it was noted that these levels of energy use are probably closer to the level that is objectively necessary to sustain life than to what may be regarded as acceptable minimum levels of energy use. Whether this is indeed the case requires further study. They are therefore open to dispute. Despite this the above two lines appear to be reasonable estimates given that they are about 10% greater than the average levels of energy consumption in rural areas of what was Bophuthatswana which Eberhard and Dickson (1991:34-35) describe as "unsatisfactory".

Ideally, a number of energy poverty lines that take variations in climate, altitude, staple diet and available energy sources into account should be specified. These could then be further refined by what is regarded as the acceptable minimum levels of energy consumption in each of the phases of the energy transition process. However, the data needed to specify a range of energy poverty lines are lacking. Another consideration is that the simplicity inherent in using a single energy poverty line would be lost if a range of such lines were to be estimated.

There are three further drawbacks associated with using the energy poverty lines specified above. Firstly, the poverty lines specify the amount of energy a person needs *per year*. This hides the fact that people need access to energy resources on an almost continuous basis. It must therefore be assumed that the amount of energy specified by the poverty lines is a flow - with some seasonal variation - spread throughout the year, as opposed to a stock received at a specific time and which has to be rationed until the next amount becomes available. It may be useful to regard an energy poverty line as referring to the sum of a person's daily energy needs during the course of a year. Secondly, the energy poverty lines refer to desirable levels of *per capita* energy consumption rather than desirable levels of *household* energy consumption. This overcomes the discrepancies that would exist due to the differing size of households, but it ignores the economies of scale that characterise most domestic uses of energy. Thirdly, these poverty lines can only identify areas where the average level of energy consumption is unsatisfactory, but not sufficient information is available to estimate the number of households suffering from energy poverty in each of the areas.

The rest of this section uses the energy consumption data presented in section 4.8 to identify and discuss energy poverty in South Africa. The figures that follow are based on the data in the final columns of tables 4.14 and 4.16 respectively. Figure 6.1 presents the results of taking the nett energy consumption totals for the different samples and calculating to what extent they differ from the nett energy poverty line (10 GJ per capita per year). The zero line therefore represents the break-even point. Households with energy consumption levels below this line are assumed to be suffering from energy poverty. Households above the line are consuming sufficient energy to meet their basic needs. Figure 6.2 is calculated in the same way, except that useful energy and the useful energy poverty line (1.5 GJ per capita per year) are used.

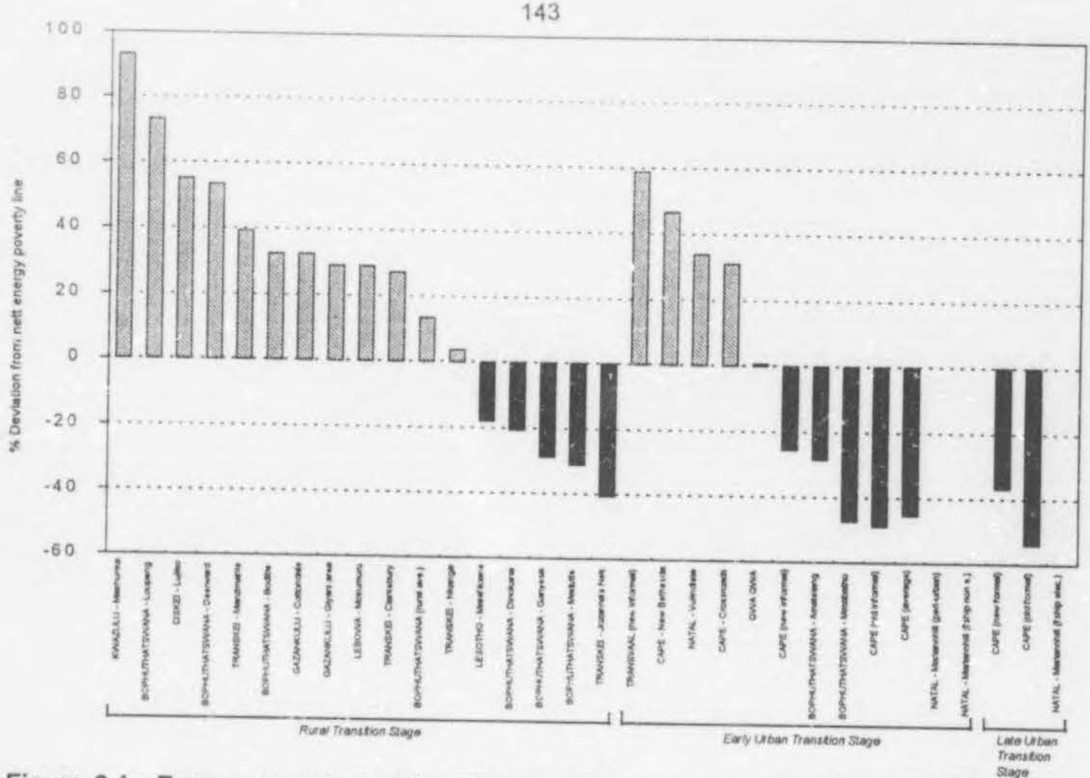


Figure 6.1: Energy poverty as identified by the nett energy poverty line (10 GJ per capita)

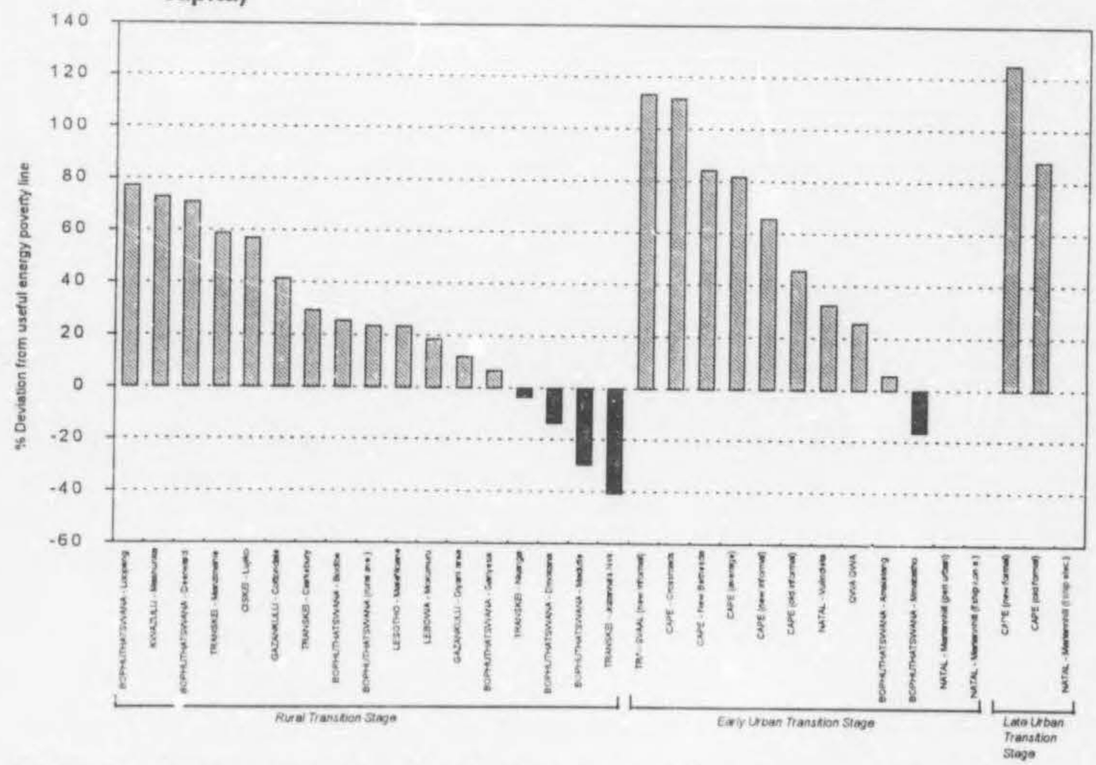


Figure 6.2: Energy poverty as identified by the useful energy poverty line (1.5 GJ per capita)

According to the data in figure 6.1, energy poverty occurs in the highlying areas of the former Transkei, is widespread in the former Bophuthatswana and is particularly acute in the black townships around Cape Town. Figure 6.2 gives a slightly different picture. The areas around Cape Town, as well as some other areas, that fell below the nett energy poverty line do not fall below the useful energy poverty line. However, all the areas that do fall below the useful energy poverty line also fall below the nett energy poverty line. This suggests that the useful energy poverty line gives a narrower definition of energy poverty than the nett energy poverty line. However, it may also be that the energy efficiency ratings assigned to the different energy sources in table 4.2 produce some distortion given the varying patterns of energy use in the different areas. For instance, in the Cape samples paraffin and gas predominate. So though the nett energy consumption levels are very low, even below the nett energy poverty line (see table 6.1), the high energy efficiency ratings of these two fuels mean that the levels of useful energy consumption appear to be satisfactory, i.e. above the useful energy poverty line (see table 6.2).

Obviously not all households in the areas with energy consumption levels below the respective poverty lines are in a state of energy poverty. The aggregation of the data and the fact that it is based on total samples rather than households "using the energy source" hides such variances. Nevertheless a low average level of energy consumption suggests that energy poverty is widespread among households in these areas. The use of aggregation also means that even in areas where the average levels of energy consumption are above the poverty lines there may still be individual households suffering from energy poverty.

Although the geographical spread of the samples in the above figures is limited, it is sufficiently broad to suggest that energy poverty is a problem in many areas in South Africa. Closer examination of locality and energy consumption patterns of the samples that fall short of the energy poverty lines suggests that households living in arid and semi-arid areas (Bophuthatswana samples), as well as in the high lying areas along the Eastern escarpment (Malefiloane, Jozanna's Nek and Nkanga samples) are particularly at risk. In all these areas fuelwood is scarce and access to alternative energy supply networks limited. Other areas where households are likely to be at risk are densely populated resettlement areas (Qwa Qwa) and peri-urban areas (Cape samples). In these areas fuelwood is generally unavailable and many households do not have the income to purchase paraffin or gas.

The energy consumption patterns of the samples indicate that in rural areas it is households that are making the transition from the first phase of the rural energy transition to the second phase that are particularly at risk. In section 2.3.3.3 it was noted that households in this position are likely to experience a decline in their level of energy consumption and may have "little option, but to make greater use of dung and crop wastes". The widespread use of these fuels in the samples that fall below the poverty lines confirm that households are being sorely pressed to maintain their levels of energy consumption. In urban areas households in the first and second phases of the urban transition process are the ones particularly at risk. As noted in section 2.3.3.3, 'free' biomass fuels are unavailable in urban areas, which means households have to rely on commercialised energy sources. Households with low incomes cannot afford to purchase the energy they require, forcing them into a state of energy poverty. Figure 6.2 seems to suggest that energy poverty occurs less frequently in urban areas than in rural areas. However, this interpretation of the figure is subject to the caveat relating to the energy efficiencies noted above. It may also simply be a function of the limited spread of the samples available for the analysis. There is nevertheless clear evidence that very few households with access to electricity suffer from energy poverty. A plausible explanation for this state is that in the past only households that could afford electricity were given access. Whether this will change with the widespread electrification is an open question. It is possible that with electrification households may divert energy from essential to less essential uses and so continue to experience the consequences of energy poverty even though their level of energy use may remain the same or even increase.

6.1.2 The use of energy for essential energy services

Table 6.1 presents estimates of how households divide their energy budgets between different uses at various stages in the domestic energy transition. Estimates are used because data measuring this aspect of energy use are not readily available, especially during the rural and early urban stages of transition. In drawing up table 6.1, cognisance was taken of information from the following sources: Cecelski *et al.* (1979:20), Best (1979:23), Flavin (1986:40), Rivett-Carnac (1990:34 and 36), and Eberhard and Dickson (1991:35).

Table 6.1: Estimated breakdown of domestic energy consumption between uses

Activity	% of Household energy budget		
	Rural stage	Early urban stage	Late urban stage
Cooking	60 - 90	40 - 70	20 - 50
Heating water	10 - 15	15 - 30	30 - 50
Providing warmth	5 - 20	10 - 20	10 - 30
Lighting	2 - 5	5 - 10	10 - 15
Refrigeration	< 1	< 2	10 - 20
Television	< 1	< 2	2 - 5
Other appliances	< 1	< 5	10 - 20

The following points are relevant in the interpretation of this table: firstly, it cannot be overemphasised that the figures are estimates and, hence, are open to dispute; secondly, the figures indicate the range in which household energy choices are most likely to fall; thirdly, the figures do not equal 100% when added vertically because allowance is made for variations in energy use patterns; and lastly, using percentages hides the disparities that exist in the quantity of energy used for different tasks at different stages of the energy transition. For instance, the significant decline in cooking's share of the energy budget reflects an increase in the amount of energy used for other purposes rather than a fall in the amount of energy used for cooking. Ideally, table 6.1 should be based on data giving a detailed breakdown of the actual amounts of useful energy households devote to different tasks. This could then be complemented by data reflecting the amount of energy needed to fulfil basic needs and the amount needed to maintain an acceptable standard of living. If such data were available it could be used to identify the specific energy services that need to be increased or altered in order to enhance household welfare.

In the ensuing paragraphs the trends evident in table 6.1 are discussed, together with other information relevant to the impact that using energy for cooking, heating water, providing warmth, and other services has on household welfare.

(a) *Cooking*

According to the estimates in table 6.1, cooking is probably the most important use of energy in both the rural and early urban stages of the domestic energy transition. Two explanations for this may be offered: one, the limited amount of energy available is used for the most basic need, and two, the energy sources used are not very versatile and the appliances needed to diversify are too expensive. In the late urban stages of the energy transition the proportion of the energy budget used for cooking tends to decline. The principal reason for this (as already noted) is that more energy is used to provide other energy services. As energy consumption levels increase, it seems reasonable to presume that a ceiling exists on the amount of energy households can reasonably use to cook three meals a day. The existence of such a ceiling is supported by data referred to by Cecelski *et al.* (1979:20). More important, from a basic needs point of view, is the determination of what may be termed the cooking energy threshold, i.e. what is the minimum amount of energy a household needs for cooking in order to maintain health and an acceptable standard of living. A simple answer does not appear to be available due to the diversity in people's diets and cooking practices. Tables 6.2 and 6.3 present data on energy used for cooking derived from Lennon and Turner (1991:8), who calculated the amount of energy needed to cook a basic meal on different energy sources, and from Rivett-Carnac (1990:29), who estimated the cost of fuel used for cooking in households in the Mariannhill area.

Table 6.2: Energy used for cooking according to Lennon and Turner (1991)

Energy source	Energy used to cook a basic meal[1] (MJ)	Energy used for cooking per year (MJ) [2]	(energy source)
Electric stove	1.7	1 550	430 kwh of electricity
Coal stove	4.8	4 370	161 kg of coal
Coal fire	14.4	13 100	485 kg of coal
Wood stove	4.8	4 370	256 kg of wood
Wood fire	14.4	13 100	770 kg of wood

Source: Lennon and Turner, 1991:8
Notes: 1. Assumed that 2.5 meals are cooked per day during the course of a year.
2. Conversions based on calorific values in table 4.1.

Table 6.3: Energy used for cooking according to Rivett-Carnac (1990)

Energy source	Monthly expenditure on cooking	Energy cost used for conversion[1]	Energy used for cooking per year (MJ)[2]	(energy source)
Fuelwood (fire)	R17	9 c/kg	38 500	2 270 kg
Paraffin	R16	67,5 c/l	10 500	284 l
Gas	R25	1,7 R/kg	8 600	176 kg
Coal	R26	24,5 c/kg	34 400	1 270 kg
Electricity	R33	9,03 c/kwh	15 800	4 385 kwh

Source: Rivett-Carnac 1990:29
Notes: 1. Based on energy costs in Rivett-Carnac (1990:30).
2. Conversions based on calorific values in table 4.1.

There is no indication whether the basic meal referred to in table 6.2 is for a household of say five or six or for a single person. Comparing the tables it would appear to be the latter, in which case the physical quantities of energy used do not appear to be consistent with the per capita energy consumption data in table 4.12. The second table is based on household data and the physical quantities of each energy source used compare well with data in table 4.11. It may, therefore, be assumed that the cooking energy threshold is probably some way below the levels of energy use noted in the latter table. Exactly how far below remains uncertain without access to better information. Even without the aid of such a measure it is fairly obvious that in areas such as Amatelang, in what was Bophuthatswana, and in the former Qwa Qwa energy is so scarce or households so poor that many cannot afford to cook every day, while many more only cook once a day (Eberhard, 1986:59 and 96). It is almost certain that the limited availability of cooked meals affects people's nutritional status, but information on the links between cooking and nutrition could not be found.

Many other aspects of using energy for cooking affect household welfare. To start with, the type of energy used can be assessed in terms of its affordability, acceptability, efficiency and convenience. Most of these aspects are considered elsewhere. Then there is the type of stove (or lack thereof) and the range of pots and other appliances households own (discussed in section 6.2.4(a)). The many culturally determined cooking practices and habits are also important, especially aspects such as cooking indoors without ventilation (section 5.2) and the social function of the hearth. Finally, there are the many ways in which the level of welfare derived from using energy for cooking may be improved: energy-efficient stoves, smoke removal and conservation measures, as well as policies to ensure adequate supplies of energy. Most of these are referred to in other sections, especially section 7.2.3.

(b) *Heating water*

A distinction must be drawn between heating water for tea/coffee and for washing, bathing and cleaning purposes. The former use of hot water is very closely related to cooking, not only because it is for drinking, but also because the appliances used to perform the task are the same, with the exception of kettles - especially electric kettles. In rural and peri-urban areas that do not have access to reliable, clean water supplies, boiling drinking water reduces the risk of contracting gastro-enteritis, cholera, typhoid, dysentery and bilharzia. The prevalence of these diseases suggests that households may be unaware of the health benefits of sterilising water. Education needs to fill this gap, as well as measures to give people access to clean water (Wilson and Ramphele, 1989:112). Another possibility is that households that barely have enough energy for cooking, cannot afford to boil water as well. One form of poverty, thus, compounds other forms.

The proportion of energy used to heat water for washing, etc. tends to increase gradually across the domestic energy transition as a whole, with a dramatic increase occurring when households gain access to electricity, and more especially a geyser. This is reflected in table 6.1. In the rural and early urban stages the fire used for cooking invariably also heats water, otherwise a primus stove is used (Eberhard, 1985:63). The water is used primarily for bathing and washing dishes; little is used for cleaning the household or for laundry.

This relatively stable pattern of hot water use changes when households gain access to piped water, and if they then install a gas water heater. However, the proportion of the energy budget used for heating water is still only about half that used for cooking. When households gain access to electricity, however, it is not unusual for more energy to be used for heating water than for cooking. The convenience of hot water on tap encourages bathing and showering, it is used for washing laundry and in dishwashers as well as innumerable other house cleaning tasks. Eskom estimated that a family of four requires about 540 kwh per month for heating water, which is double the estimated amount needed for cooking (Rivett-Carnac, 1990:34-36).

From the above discussion it is evident that as the domestic energy transition takes place, households gain access to energy sources (and appliances) that facilitate the heating of water and, hence, increase the amount of welfare households derive from this energy service. The increased availability of hot water encourages a higher standard of personal and household hygiene, which has both health and social benefits. However, the use of electric geysers often leads to excessive hot water use. In such cases welfare could probably be enhanced by using hot water more judiciously and saving the energy used to heat it.

(c) *Providing warmth*

The use of energy for providing warmth or for space heating is a basic need when temperatures drop sufficiently to threaten people's health, otherwise it is a non-essential, though often very welcome, energy service that enhances the amenity of the indoor environment.

The factors that determine how much energy is used to provide warmth also affect how much welfare households derive from the service. They include the climate, season and temperature, the altitude, aspect and location of the dwelling, its design, the size of the household and their personal characteristics (age, health, diet and acclimatisation) and, of course, the type of energy, the appliances and energy conservation measures used. Due to variations in these factors the amount of energy used for space heating differs widely between regions. The estimates in table 6.1 take this into account in the range of possible energy budget proportions households might use to provide warmth. The mild climate along the eastern seaboard means households need to use a very small proportion of their energy budget for space heating, whereas in inland areas the proportion is far higher because it is colder and more heating is needed. The proportion tends to be highest in the Drakensberg, the Transvaal Highveld, Free State, Karoo and Boland where night-time temperatures regularly fall below zero in winter. Access to energy sources in these areas may be critical to welfare, if not to life.

In the early rural transition, households have access to sufficient fuelwood to meet their space warming needs. The cooking fire is usually used to warm the house as well. The households most at risk from cold are those in the late rural and early urban stages of energy transition, especially those too poor to buy commercialised energy sources. These households burn dung, crop residues and any other wastes to provide warmth. There are even reports of people removing window frames from deserted houses, or cutting down their own fruit trees to burn (Wilson and Ramphele, 1989:46). Households that are slightly better off may use coal, most often burning it in a brazier. The health risks this creates are discussed in section 5.2.4.

In the middle phase of the urban transition, households may use a variety of energy sources and appliances for heating. Hearth fires and wood/coal stoves are common, paraffin heaters less so, while gas heaters are rare. Once a household gains access to electricity, the amount of energy used for space warming tends to increase significantly both in absolute terms and as a proportion of the energy budget, as reflected in table 6.1. Most of this energy is used for non-essential space warming aimed at creating a comfortable indoor environment. The use of air-conditioners for cooling should be regarded in the same light.

A notable aspect of this particular energy service is the large number of conservation measures households at all stages in the energy transition process can adopt in order to reduce their "heating bills". The various measures are discussed in some detail in section 7.2.

(d) *Lighting*

Lighting is not an absolute necessity, yet apart from the above three energy services, it is the only other to feature prominently in all stages of the domestic energy transition. This is reflected in table 6.1. Lighting's share of household energy budgets tends to increase as the energy transition progresses. It would seem that improvements in the quality of lighting, changing habits and greater ability to pay encourage use.

Candles seem to be the predominant source of lighting at all stages of the transition process until households gain access to electricity. The use of candles is dictated by necessity and the fact that they are readily available and relatively affordable. Households that are slightly better-off also use a variety of paraffin and gas lamps. Table 6.4 gives an indication of lighting practices in rural, village and peri-urban areas. Those in non-electrified urban areas are not dissimilar, except that wet-cell batteries are used as well (Eberhard 1986,66 and 100; Rivett-Carnac, 1990:33).

Table 6.4: Energy sources and appliances used for lighting

Area	Hours of lighting per day	% Households using energy source			Ownership of lighting appliances (%)		
		candles	paraffin	gas lamp	paraffin lamp	gas	torch
Lujiko	2.7	42	98	-	96	2	57
Manzimahle	3.8	40	70	4	79	4	44
Clarkebury	4.5	73	42	10	68	6	22
Nkanga	2.9	64	36	-	64	-	18
Cottondale	4.1	44	60	2	71	2	31
Mokumuru	3.3	53	67	-	90	7	50
Vulindlela	2.9	79	24	-	39	5	45
Qwa Qwa	3.7	94	19	-	45	8	17
Amatelang	4.2	97	40	-	41	8	49
New Bethesda	3.0	78	90	-	91	3	69
Crossroads	-	51	84	2	84	?	?

Source: Eberhard 1986:66 and 100

When households gain access to electricity, their use of lighting takes a quantum leap primarily because of the quality and convenience of electric lighting. The increase in consumption is invariably sufficient to off-set the fact that electricity is more cost-efficient than all other sources of lighting (Rivett-Carnac, 1990:33).

The amount of welfare derived from lighting is affected by the amount consumed, the quality and cost thereof, the risks associated with its use and its convenience. Less obvious are the cultural and social impacts that access to lighting have and their relationship to welfare. These aspects are discussed in section 6.2.4(b). Section 7.1.4(b) discusses the importance of lighting and makes a number of recommendations on ways of ensuring as many households as possible are able to benefit from good quality lighting.

(e) *Other energy services*

None of the remaining energy services are essential or approach the importance of lighting, yet their contribution to household welfare can still be substantial. Access to these services is invariably dependent on the purchase of the appropriate appliances as well as access to electricity, which is why their share of household energy budgets in table 6.1 is insignificant until the late stages of the urban energy transition.

Out of the range of energy services, refrigeration and forms of home-entertainment (television, video and hifi's) are probably the next most important after those already discussed. The use of energy for home entertainment is discussed in section 6.2.4(c). As regards refrigeration, Rivett-Carnac (1990:35) notes that refrigerator ownership is almost universal among electrified households in the Mariannhill area, while paraffin and gas refrigerators are not uncommon in other households. This points to a high regard for the services a refrigerator provides and suggests the welfare benefits of refrigeration are large - at least sufficient to off-set the opportunity costs of a fairly high capital outlay and ongoing energy costs.

The extensive use of energy for non-essential tasks and services in the late stages of the urban energy transition raises a number of issues. Firstly, each of the services enhance the welfare of the households using it, but that does not imply that they enhance social welfare as well. The social cost of the energy may be greater than the private benefit derived from its use due to external (environmental) effects. Secondly, the energy-intensive life-style encouraged by the use of electricity is not environmentally sustainable. Thirdly, it is problematic both from a political and from an ethical perspective that there are people unable to meet their basic energy needs while alongside them others are using excessive amounts.

6.2 Energy use and the intermediate goals of welfare

This section examines ways in which the use of energy affects the attainment of needs/desires other than basic needs. As noted above, these other needs/desires are described by Terreblanche (1986:58) as the intermediate goals of social welfare. He identifies four broad categories or goals: (i) growth and efficiency, (ii) stability, (iii) distribution or equity and (iv) civilisation and culture. The relationship between these goals of social welfare and energy use was summarised in table 1.1. For ease of reference this table is presented again below.

Table 1.1: The intermediate goals, principles and energy variables for the attainment of social welfare

Intermediate goals (guiding principles)	Energy related factors that affect each goal
the growth and efficiency goal (economic and distributive efficiency)	- percentage income spent on energy - price/cost of energy sources - appliance prices - efficiency of consumption
the stability goal (security and continuity)	- reliability of energy supply - stability of energy and appliance prices - provision of physical security
the distribution or equity goal (fairness and justice)	- effect of policies on access to energy sources - lack of credit to purchase appliances - incidence of energy subsidies
the civilisation goal (raising/maintenance of moral and cultural values)	- possession of appliances - lighting - entertainment opportunities - modernisation

Source: The intermediate goals are identified by Terreblanche 1986:58

There is no clear-cut distinction between aspects of energy use relevant to the attainment of these intermediate goals of welfare and the basic energy needs discussed in the previous section. For example, expenditure on energy sources, prices of energy and of appliances are all in some way relevant to the fulfilment of basic energy needs, as well as the intermediate goal of growth and efficiency. Furthermore, these aspects of energy use may also affect the attainment of other intermediate goals such as the stability or equity goals. It cannot be overemphasised that all dimensions of welfare are interdependent, even though it is not always possible, as in this section, to analyse all the links that exist.

The structure of this section is based on the above table. Since the different sections are widely separated from each other, a brief introduction follows. It aims to give a broad picture of how the different goals relate to household welfare and which aspects of energy use are relevant to the attainment of the different goals.

The intermediate goals, energy use and household welfare

(i) *Growth and efficiency goal* This goal, according to Terreblanche (1986:54), has to do with the fundamental economic problems of resource mobilisation, goods production and the allocation of both to satisfy people's needs. He argues that for the goal to be realised, resources (factors of production) must be developed and used effectively. There must be both static and dynamic economic efficiency in the mobilisation of resources and production of goods, and goods must be of such a nature and be allocated in such a way as to ensure that individual, collective and future needs can be satisfied.

Many aspects of energy use are relevant to the attainment of the growth and efficiency goal. For instance, the mobilisation of energy resources, the conversion of primary energy resources into usable forms and the distribution of energy through various networks must each be done as effectively and efficiently as possible. Much of chapter 5 is also relevant as it is concerned with the sustainable use of the environment and the various essential services it provides. Chapter 7 is also relevant as much of it is concerned with the efficient use of energy in the household. The discussion in section 6.2.1 focuses, however, on those aspects of domestic energy use directly linked to the use of household resources, particularly income, time and fuels. To be more specific, the section looks at domestic expenditure on energy sources, the cost of different energy sources, the price of appliances and the efficiency of energy use.

(ii) *The stability goal* The conditions which Terreblanche (1986:55) suggests are necessary for the realisation of the stability goal include a high level of economic activity with high rates of employment, a stable socio-political environment, stable external political relations, a balanced international trade account and low inflation. The links between these conditions and domestic energy use may seem rather tenuous, but they are there and are important.

Continuity in the supply of energy to households is an integral aspect of a well functioning economy; changes in energy and appliance prices have an impact on inflation; and the importation of petroleum affects the trade balance. The guiding principle of "security and continuity" suggests that physical security is also important to the attainment of the stability goal, i.e. household welfare can be enhanced when households use energy, along with various devices, to protect themselves and their possessions. The discussion in section 6.2.2 looks specifically at the reliability of energy supplies, the stability of energy and appliance prices and the use of energy to provide physical security.

(iii) *The distribution or equity goal* This goal requires that both the material and non-material costs and benefits of economic activity, as well as opportunities it affords, be divided reasonably fairly between individuals and constituent groups of society. At very least, people should have access to sufficient resources to satisfy their basic needs (Terreblanche, 1986:55).

Any discussion of equity in South Africa usually draws attention to the disparities in income, wealth and land ownership between the racial groups or between urban and rural areas. There is also another dimension of inequality, namely unequal access to energy resources, particularly electricity in the domestic sector.

At various points in chapter 5 reference was made to the unequal way the environmental costs and benefits of energy use are divided between races and between urban and rural areas. It was evident that those lacking income and wealth (and political power) also do not have access to the more modern energy sources. The possibility that different forms of inequality are correlated with each other is touched on in section 6.2.3, but is not fully investigated. The issues discussed focus on the role of government in determining differential access to energy resources, the availability of credit to purchase appliances and the possible incidence of energy subsidies.

(iv) *Civilisation goal* This goal is far less concrete than the others. How does one measure civilisation? What are the moral and cultural values referred to in the guiding principle? What factors promote civilisation? With regard to the last question, Terreblanche (1986:55) argues that the civilisation goal can only be satisfactorily realised if, among other things, people enjoy sufficient freedom to allow them to develop as persons. While the use of energy can affect the existence of civil freedom in only a very round about way, there are certain energy uses that may facilitate the process of personal development. Notable examples include home lighting and access to audio-visual appliances. Access to more convenient and efficient (modern) energy sources and appliances also seems to have an impact on households' level of modernisation.

Modernisation is also usually associated with changes in moral and cultural values. Since many of these values underpin any concept of civilisation, changes to them are relevant to the civilisation goal. What exactly the relationship is depends on a subjective assessment of what is desirable and what is not, and what contributes to civilisation and what does not. Indeed, even the concept of civilisation is subjective. Despite these caveats, the western/modern/materialist interpretation of civilisation is implicit to the discussion in section 6.2.4. The issues examined there include appliance ownership, the use of lighting and the role energy plays in home entertainment opportunities.

6.2.1 The growth and efficiency goal

(a) *Domestic expenditure on energy sources*

Expenditure on energy sources refers only to the cost of purchasing energy and should be distinguished from expenditure on energy services, which incorporates the capital cost of appliances and other fittings as well. At a theoretical level the expenditure on energy services would give a truer picture of what the use of energy costs a household, but since it is far easier to collect data on expenditure on energy sources, this measure is generally used.

Expenditure on energy sources is relevant to the attainment of the growth and efficiency goal in so far as it indicates how households allocate their resources, in this instance income, between different uses in their effort to maximise welfare. In the subsections that follow the relationship between expenditure on energy sources and household welfare is examined from three perspectives: expenditure on energy sources, percentage income spent on energy, and energy sources and income levels.

But first expenditure data from five of the studies referred to in chapter 4 are presented in table 6.5. In order to facilitate comparisons between the studies, the annual expenditure on the individual energy sources is expressed as a percentage of the households' total annual expenditure on energy which is given in the "Total given in source" column. In all cases the data are based on *whole sample* aggregates. The Rivett-Carnac (1990) study does not present a breakdown of energy expenditures based on the whole samples. He only presents expenditure data for those households using the individual energy sources (see Rivett-Carnac, 1990:20-21). This is not comparable to the data from the other studies and so is not presented here. The other blank spaces in the table either indicate that the households in the sample did not purchase the particular energy source or they only purchased negligible amounts (this is an assumption based only on the fact that expenditure figures on these energy sources are not reported). The second column from the right expresses the total annual expenditure values given in the third column from the right in 1990 Rands (the Consumer Price Index (CPI) was used in the conversion (SARB, 1994:S-118)). These amounts are comparable. The column furthest to the right expresses the households' total annual expenditure on energy sources as a percentage of their total annual income. Ideally, the households' total annual expenditure on energy sources should also be expressed as a percentage of their total annual expenditure so as to get an idea of the importance of energy in household consumption budgets. However, the data to do this were only available in a number of the studies, so it was not done.

Table 6.5: Annual expenditure on energy sources per household

Area	Source	Date	Wood	Paraffin	Coal	Gas	Electricity	Candles	Dry-cell	Wet-cell	Total given in source	Adjusted total (1990R)	% of household income
Rural Transition Stage													
Lesotho - Malefiloane	Best	1979	-	100	-	-	-	?	-	-	(1978) 6.36	35.3	2.5
Transkei - Jozanna's Nek	Best	1979	-	100	-	-	-	?	-	-	(1978) 12.48	69.3	3.0
KwaZulu - Mashunka	Best	1979	-	100	-	-	-	?	-	-	(1978) 6.60	36.6	3.6
Ciskei - Lujiko	Eberhard	1986	61.3	36.6	-	-	-	2.1	-	-	(1984/5) 170	402.8	) income data
Transkei - Manzimahle	Eberhard	1986	47.8	42.2	2.7	1.1	-	6.1	-	-	(1984/5) 229	542.7	) not accurate
Transkei - Clarkebury	Eberhard	1986	42.9	26.8	13.1	7.4	-	9.8	-	-	(1984/5) 269	637.4	) - estimated
Transkei - Nkanga	Eberhard	1986	62.9	22.3	-	3.4	-	11.5	-	-	(1984/5) 187	443.1	) to be
Gazankulu - Cottondale	Eberhard	1986	30.3	36.6	16.5	3	-	13.5	-	-	(1984/5) 271	642.2	) 10 % on
Lebowa - Mokumuru	Eberhard	1986	-	56	5.5	-	-	37.8	-	-	(1984/5) 55	130.3	) average
Bophuthatswana - Bodibe	Eberhard[1]	1991	14.4	43.7	18.9	-	-	23.1	-	-	(1987) 213	315.1	17.1
Bophuthatswana - Madutle	Eberhard[1]	1991	3.4	62.8	2.1	-	-	31.4	-	-	(1987) 98	145.0	6.9
Bophuthatswana - Dinokana	Eberhard[1]	1991	14.9	52.8	9.6	-	-	2.27	-	-	(1987) 196	289.9	16.4
Bophuthatswana - Ganyesa	Eberhard[1]	1991	25.1	43.8	2.1	11.1	-	18	-	-	(1987) 308	455.6	18.7
Bophuthatswana - Deerward	Eberhard[1]	1991	13	56.4	20	10.6	-	17.5	-	-	(1987) 339	501.3	14.2
Bophuthatswana - Loopeng	Eberhard[1]	1991	29.2	37.3	5.9	13.4	-	14.2	-	-	(1987) 348	514.8	11.9
Bophuthatswana (rural average)	Eberhard[1]	1991	-	-	-	-	-	-	-	-	(1987) 247	365.4	12.7
Early Urban Transitional Stage													
Natal - Vulindlela	Eberhard	1986	55.1	18.8	1.1	2	-	13.1	9.9	-	(1984/5) 352	834.1	10.7
Qwa Qwa	Eberhard	1986	13	24.5	43.8	4.3	-	9.9	4.3	-	(1984/5) 322	763.0	14.1
Bophuthatswana - Amatelang	Eberhard	1986	20.7	27.1	38.6	5	-	8.2	0.1	-	(1984/5) 280	663.5	16.5
Cape - New Bethesda	Eberhard	1986	44.3	37.4	4.9	1.6	-	7.1	4.6	-	(1984/5) 336	867.3	15.9
Cape - Crossroads	Eberhard	1986	19.4	40.2	16.8	2.2	-	4.2	8.4	-	(1984/5) 696	1649.3	19.9
Cape (old informal)	Viljoen	1990	3.5	55.7	-	21.7	-	6.7	4.9	7.4	(1988/9) 497	651.4	7.0
Cape (new informal)	Viljoen	1990	12.4	46.1	-	18.4	-	6.6	5.3	11.2	(1988/9) 370	484.9	7.1
Cape (average)	Viljoen	1990	2.4	32.1	-	30.4	18	5	3.8	8.3	(1988/9) 624	817.8	8.3
Transvaal (new informal)	Viljoen	1990	7.4	13.8	50.6	11.1	-	9.4	5.3	2.5	(1988/9) 939	1230.7	8.6
Natal - Mariannhill (peri urban)	Rivett-Carnac	1990	-	-	-	-	-	-	-	-	(1989) 668	763.4	6.0
Natal - Mariannhill (t'ship non e.)	Rivett-Carnac	1990	-	-	-	-	-	-	-	-	(1989) 549	627.4	5.3
Bophuthatswana - Mmabatho	Eberhard[1]	1991	18.5	48.8	8	8	-	12.5	-	-	(1987) 344	508.9	13.9
Late Urban Transition Stage													
Cape (old formal)	Viljoen	1990	0	22.4	-	24.8	42.5	2.4	2.3	5.6	(1988/9) 728	954.1	8.2
Cape (new formal)	Viljoen	1990	9	21.6	-	47.1	7.6	6.3	3.9	12.6	(1988/9) 864	1132.4	10.5
Natal - Mariannhill (t'ship elec.)	Rivett-Carnac	1990	-	-	-	-	-	-	-	-	(1989) 869	993.1	5.3

(i) *Expenditure on energy sources* It seems reasonable to assume that as expenditure on energy sources increases, so does household welfare, so long as prices, etc. remain constant. Nevertheless, this by no means implies that expenditure on energy is in itself an adequate indicator of welfare derived from energy. There are too many other factors that need to be taken into consideration; for instance, how the energy is used, the effect this use has on the environment, the amount of non-commercial energy households use, etc. Expenditure on energy sources is, however, an important determinant of the amount of energy households have available to them and, hence, of the welfare they derive from energy.

The fact that the energy sources that households purchase tend to be more efficient, convenient and versatile than the non-commercial energy sources also suggests a positive relationship between expenditure on energy sources and household welfare. However, this may not always be the case; for instance, if a household purchases coal instead of using fuelwood, the increased expenditure is unlikely to enhance household welfare. Differences in the relative cost of useful energy derived from each energy source may also tend to counteract the positive relationship. This is an important factor when comparing the welfare impact of expenditure on energy sources at different stages of the domestic energy transition process. Households in the later stages of the urban transition are likely to derive more welfare from the same level of expenditure than those in the early stages because of differences in the cost of energy derived from electricity compared to that derived from paraffin, coal and gas, as well as the differences in the quality of energy service derived from these energy sources. Yet another example of where the positive relationship may not hold is when households that have access to free fuelwood are compared to those that are reliant on commercial fuels.

Various trends in the expenditure on individual energy sources are also evident from table 6.5. Immediately apparent is the high proportion of expenditure used to obtain fuelwood in many areas, particularly in the former Transkei. It would appear that the scarcity of fuelwood in rural areas has led to commercialisation, while in peri-urban and urban areas very little is available and so little is purchased. The proportion of expenditure spent on paraffin shows less variation between the rural and early urban stages of the energy transition. It is the most important energy source in terms of expenditure in areas where households do not have ready access to commercialised fuelwood or where households have progressed to using gas and/or electricity. From table 6.5 it would appear that coal is rarely an important energy source in terms of expenditure. However, this impression is probably erroneous, merely reflecting a lack of data from those areas where coal is used, namely Gauteng, Mpumalanga and KwaZulu-Natal. Data in Eberhard and Trollip (1992:23) seem to confirm this. Gas is a minor fuel in terms of expenditure in all areas, except in the Western Cape, where it seems to be used instead of fuelwood and coal. However, it may also be that the households sampled in this area have simply progressed further in the energy transition process than households in most of the other samples. The proportion of expenditure used to purchase candles tends to be highest in rural areas, while the actual levels of expenditure between the rural and early urban stages of the energy transition are similar. In all cases the relatively high expenditure on candles points to the fact that they are an expensive source of lighting. Indeed, the data presented in section 6.2.1(b) below confirm that for the same level of expenditure, households with access to electric lighting derive far more welfare than households using candles. The data on the expenditure on batteries are insufficient to identify trends, except probably to note that if the proportion is as high in all areas as it is in those areas where it is measured, i.e. they are not an unimportant component of energy expenditure.

There is no lack of data on household expenditure on electricity, but very little of it gives the expenditure on other energy sources as well. Therefore, unless such households only consume electricity, the data are not comparable with that presented in table 6.5. The issue of expenditure on electricity (service charges) is a topic of study in itself, especially in the light of Eskom's high capital outlay in the electrification of households with relatively low incomes and the problems being experienced with (i) getting households to consume sufficient electricity to make the programme viable, (ii) the willingness of households to actually pay for electricity and (iii) the ability of households to purchase sufficient electricity to meet their energy needs. These issues are dealt with here simply because they are too complex to tackle within the confines of a study on the domestic energy transition process.

(ii) *Percentage income spent on energy* From table 6.5 it is evident that some households may spend almost a fifth of their income on energy, while most spend between 7% and 12%. The level seems to be higher in rural and peri-urban areas than in urban areas. Possible reasons for this are that income earning opportunities and incomes tend to be higher in urban areas, and energy sources may be more expensive in rural and peri-urban areas (Rivett-Carnac, 1990:18-19). The poor design of houses in these areas, necessitating greater use of energy for space warming, is also a factor.

How the percentage income spent on energy is related to welfare seems to depend on the particular household's circumstances. For instance, a low percentage may be feasible in rural areas with access to free fuelwood, which would mean income would be freed for other uses. By contrast, a low percentage of income spent on energy during the late rural or early urban stages of the energy transition could signify severe energy poverty, since these households often do not have large incomes and only very limited access to free energy resources. Another possibility is that the percentage is low because the households concerned have large incomes. This seems to be true of many households in the later phases of the urban energy transition. However, for many newly electrified low income households the convenience of electricity leads them to consume more than they can afford. As a result, it has been found that "the anxiety level of waiting for an [electricity] account at the end of the month is a major stress factor" for these households (Stavrou, 1992:7). This detrimental welfare impact could largely be eliminated by the use of pre-paid electricity cards which enable households to budget their use of electricity better.

The percentage of household expenditure or current consumption spent on energy may give a better measure of well-being than the percentage of income spent on energy. The reason for this is that "current consumption ... reflects households' ability to buffer their standard of living through saving and borrowing despite income fluctuations" (World Bank, 1990:26). Unfortunately, reliable data in this format were not available in the literature reviewed for this study, so apart from noting that it may convey a different picture of the way expenditure on energy affects welfare, not much more can be said.

(iii) *Energy sources and income levels* The causal relationship between income and the energy transition process was discussed in section 3.2.2. There it was noted that households tend to use "more modern" energy sources as their incomes rise. Data in Viljoen (1990:106), Rivett-Carnac (1990:25) and Eberhard and Dickson (1991:42-43) confirm this trend. This is hardly surprising, but how does it affect household welfare?

Higher incomes enable households to purchase or gain access to cleaner, more convenient energy sources which means they enjoy a higher standard of energy service and, hence, a higher level of welfare. Few low income households can afford the capital outlay (connection fees and appliances) required to gain access to these energy sources, particularly if it has to be paid in a lump sum, even though they may be able to afford the energy sources themselves. A possible explanation for this is that households living close to the poverty threshold simply cannot afford to divert any of their expenditure on consumption goods, such as energy which is essential for day to day survival, to capital goods, such as stoves. Their income is committed to surviving, while households with higher incomes have greater scope to budget for capital goods. This aspect is referred to again in section 6.2.1(c) below, where the prices of appliances are discussed, and in section 6.2.3(b) where the availability of credit for the purchase of appliances is looked at.

(b) *Cost of energy sources*

The cost of energy sources affects household welfare in so far as it is one of the factors determining both how much energy a household can afford to consume and which energy source or combination of energy sources a household will use. In the first instance, should the cost of energy increase relative to all other goods, welfare will tend to decrease, assuming that energy is a normal good. What proportions of the welfare change would be ascribed to the substitution and income effects cannot be determined without knowledge of the shape of a household's utility functions. Neither is it possible to calculate the nett welfare effect without such knowledge. In the second instance, a change in the relative price of energy sources will tend to cause households to consume more of the cheaper energy source. However, such changes in consumption patterns are only likely to the extent that the different energy sources are substitutes, i.e. they can be used to perform the same task. No two energy sources are perfect substitutes, but there is some degree of flexibility as to which energy sources households can use for cooking, heating water, space warming and lighting.

(i) *Nett energy and useful energy costs* The prices of different energy sources are not comparable unless they are converted to reflect either the cost of nett energy or the cost of useful energy. Table 6.6(a) summarises data on the cost of energy sources; based on this information tables 6.6(b) and 6.6(c) present data on the nett energy and useful energy costs calculated using the calorific values presented in table 4.1 and the efficiencies in table 4.2.

Table 6.6 (a): Cost of energy sources in 1990 Rands

Energy source	Eberhard (1986)	Eberhard *et al.* (1991)	Viljoen (1990)	Rivett-Carnac (1990)
Fuelwood (R/kg)	0.1 - 0.47	0.07 - 0.28	-	0.0 - 0.22
Paraffin (R/l)	1.01 - 1.26	1.1	0.66 - 0.77	0.74 - 0.79
Coal(R/kg)	0.16 - 0.55	0.12 - 0.16	0.09	0.24 - 0.32
Gas (R/kg)	1.5 - 3.95	2.21	1.13 - 1.38	1.63 - 2.23
Electricity (R/kwh)	-	-	?	0.102
Candles (R/each)	0.2 - 0.24	0.25	-	0.2 - 0.29

Table 6.6 (b): Cost of nett energy in 1990 Rands

Energy source	Eberhard (1986) (R/GJ)	Eberhard *et al.* (1991) (R/GJ)	Viljoen (1990) (R/GJ)	Rivett-Carnac (1990) (R/GJ)
Fuelwood	5.9 - 27.6	4.1 - 16.5	-	0.0 - 12.9
Paraffin	27.3 - 34.1	29.7	17.8 - 20.8	20.0 - 21.4
Coal	5.9 - 20.4	4.4 - 5.9	3.3	8.9 - 11.9
Gas	30.6 - 80.6	45.1	23.1 - 28.2	33.3 - 45.5
Electricity	-	-	?	28.6
Candles	58.0 - 69.9	72.5	-	58.0 - 84.1

Table 6.6 (c): Cost of useful energy in 1990 Rands

Energy source	**Eberhard (1986)** (R/GJ)	**Eberhard *et al.* (1991)** (R/GJ)	**Viljoen (1990)** (R/GJ)	**Rivett-Carnac (1990)** (R/GJ)
Fuelwood	45.2 - 212.7	31.7 - 126.7	-	0.0 - 99.5
Paraffin	54.6 - 68.1	59.5	35.7 - 41.6	40.0 - 42.7
Coal 39.5	-135.8	29.6 - 39.5	22.2	59.3 - 79.0
Gas 51.0	-134.3	75.2	38.4 - 46.9	55.4 - 75.9
Electricity	-	-	?	40.87
Candles	115.9 - 139.1	144.9	-	115.9 - 168.1

Notes: 1. The data on the cost of energy sources from the different studies was standardised using the CPI (SARB, 1994:S-118).
2. Calorific value of a candle is 0,00345 GJ (Eberhard and Dickson, 1992:33).
3. Energy-use efficiency of candles assumed to be 50%.

Comparing the nett energy and useful energy costs of the different energy sources it is clear that energy-use efficiency is a crucial determinant of useful energy costs, particularly of fuelwood and coal. In terms of nett energy these two energy sources are by far the cheapest, but when efficiency is taken into account they lose much of their cost advantage. From table 6.6(c) it is evident that the cost of both fuelwood and coal vary widely. In the case of fuelwood, the fact that it is a local resource means that its cost is largely determined by availability, which varies greatly from area to area. The cost of coal also varies geographically, but in this instance transport is the determining factor. Coal is generally cheaper than paraffin close to the coalfields and more expensive in areas such as the Western Cape. The consumption patterns of coal and paraffin reflect these differences. Paraffin prices do not vary much, but they appear to be slightly higher in rural and peri-urban areas. Gas can be up to 50% more expensive than paraffin and it also shows a stronger urban bias. In terms of useful energy cost, candles are the most expensive energy source. Rivett-Carnac (1990:33) calculates that a 100 watt electric filament light bulb and a 1.5 metre fluorescent tube are, respectively, 256 and 1640 times more cost efficient than a candle. Lastly, the single figure for electricity shows that although the nett energy cost of electricity is not very competitive, it is certainly one of the cheapest sources of useful energy.

With regard to the impact of energy costs on welfare in different phase of the domestic energy transition, it would appear that households in the rural and early urban phases are faced by higher energy costs than households in the late urban phases of transition. The differences arise from the fact that households in the former phases of the energy transition process are forced to consume the more costly energy sources, because they do not have access to either free fuelwood or electricity, and that energy prices tend to be higher in rural and peri-urban areas than in formal urban areas.

(ii) *The cost of 'free' energy sources* Free energy sources may not cost money, but they certainly require the expenditure of time and effort to collect and transport them to the home. As with other areas of home production, shadow prices could be used to estimate the impact that fuel gathering has on household welfare. However, this approach is not used in the literature surveyed. In the case of fuelwood, directly observable variables are used instead. Table 6.7 summarises data on fuelwood gathering.

Table 6.7: The cost of gathering fuelwood

Area	Source date	No. of trips per week	Time taken per trip (hrs)	Walking distance to collection area (km)	Average weight of headload (kg)
Lesotho: Malefiloane	Best 1979	4.38	3:10	3.5	21.30
Transkei: Jozanna's Nek	Best 1979	3.59	4:00	3.2	16.2
KwaZulu: Mashunka	Best 1979	3.41	3:30	2.5	20.62
Gazankulu: Giyani area	Liengme 1983	(3.3)	-	4-5	31.64
KwaZulu: Mahlabatini (HG)	Gandar 1984	2.0	4:30	4.2	37.9
KwaZulu: Mahlabatini (LG)	Gandar 1984	2.6	2:35	1.8	37.9
Ciskei: Lujiko	Eberhard 1986	average	4:00	3.4	)
Transkei: Manzimahle	Eberhard 1986	of	6:10	4.2	) average
Transkei: Clarkebury	Eberhard 1986	2-3	4:30	2.8	) of
Transkei: Nkanga	Eberhard 1986	times	3:40	3.8	) 30
Gazankulu: Cottondale	Eberhard 1986	per	2:40	4.7	)
Lebowa: Mokumuru	Eberhard 1986	week	3:10	3.0	)
Bophuthatswana (rural average)	Eberhard 1991 *et al.*	-	(2-6h)	6.3	-

It is abundantly clear from table 6.7 that fuelwood gathering requires a lot of time and effort. Not reflected is the fact that the task is performed almost exclusively by women which is an indication of the subordinate position women occupy, particularly in rural areas. Gandar (1984:5) observes that there is a limit to the amount of time women can spend gathering fuelwood because of commitments to other household chores. So when fuelwood becomes scarce they are unable to maintain their level of fuelwood consumption by increasing the time spent collecting it, because their time is fully committed already.

Apart from the time-cost and effort of walking long distances carrying heavy bundles, interviews with women also indicate that the risk of molestation in the woodlands, the risk of fines for cutting green wood, and the necessity to go out in all weathers and when sick are all additional "cost" factors (Wilson and Ramphele, 1989:44).

There is a lot of anecdotal information on fuelwood gathering in the literature. (See for instance: Best (1979), Liengme (1983), Møller (1985), Gandar (1984), Eberhard (1986), Cecolski *et al.* (1979), Eberhard and Dickson (1991) and Gandar (1991).) Of particular importance are reports on the gradual commercialisation of fuelwood due to the use of transport to fetch and carry it (particularly in the former Transkei) and the sale of "imported" fuelwood from coalyards in the former Bophuthatswana. These developments have caused Eberhard (1986:37) to note that "it no longer makes sense to draw a distinction between non-commercial and commercial fuels and to characterise fuelwood consumption in rural areas as being predominantly non-commercial". Indeed, it would appear that the main reason why households continue to collect fuelwood themselves is in order to conserve their financial resources for other purposes.

Collecting dung and crop residues are also time consuming tasks. Best (1979:13 and 19) describes the collection and preparation of dung in the villages of Malefiloane and Jozanna's Nek and in both instances notes that it is less time consuming and requires less effort than collecting fuelwood. This may, to some extent, compensate for the other inconveniences of using it as an energy source.

(iii) *Other costs* The cost of energy sources can be interpreted more broadly than merely financial and time costs. Associated with the use of each energy source is an array of social costs, health costs and environmental costs. How these various costs change as the energy transition process progresses and how they relate to household welfare are the subject of this study

(c) *Cost of appliances*

Table 6.8 presents information on the cost of various appliances sold in shops (including a major chain store) in Stellenbosch.

Table 6.8: Cost of appliances (Aug. 1993 - Stellenbosch)

Energy source	Appliance		Price (R)
Paraffin	Primus stove	- single plate	52 - 56
	Slow cooker	- single plate	20
		- double plate	48
	Wick lamp + glass		10
	Lamp fitting only		3.5
Gas	CADAC	- single plate	33 - 34
		- double plate	114
	CADAC - 100 cp lamp		46 - 57
	CADAC bottle	- 3 lb	84 - 103
		- 7 lb	99 - 114
		- 11 lb	119
Electricity	Single hot plate		96
	Double hot plate		146 - 249
	Table top stove and oven		700
	Four plate stove and oven		1800 - 2500
	Microwave ovens		500 - 1300
	Electric kettle		60
	Small double bar heater		68

The above table clearly illustrates the differential cost of appliances for different energy sources. Given that a stove or other appliances (apart from pots) are not essential for fuelwood or coal to be used, the cost of appliances shows a definite upward trend across the domestic energy transition process. It is for this reason that the choice of energy source is often determined by the cost of appliances rather than the cost of the energy sources themselves. For instance, while paraffin appliances cost a lot less than other types of appliances, they may still not be affordable to households that would normally purchase them. Their incomes may be so low that expenditure on capital goods such as a paraffin stove may not be possible. Even households at later phases in the energy transition and with higher incomes may not be able to progress to the next stage because they cannot afford the new appliances. The cost of appliances as well as other capital costs such as electric wiring may, therefore, be depicted as an "entry fee" which households must pay in order to progress from one phase to the next in the energy transition. At each level of income an "affordability threshold" may be postulated, i.e. how much can households spend on capital goods once all their essential consumption needs and recurrent expenditures (such as rent) have been met? If the entry fee is greater than this threshold then the household is unlikely to be able to progress in the energy transition process; the entry fee acts as a barrier.

The existence of this entry fee is well recognised with regard to electrification. Formal connection of a household to the grid costs upwards of R2300 (April 1992) (Stavrou, 1992:6-7). In addition, the installation costs are borne by Eskom or the municipality with only a nominal fee levied for hook-up. The shortfall is recovered via a surcharge on electricity consumption, as well as through cross-subsidisation by other consumers. In effect, therefore, households are being given a discount (due to cross-subsidisation) and a long-term loan in order to enable them to gain access to electricity. Sometimes electric appliances, such as stoves, kettles, irons, etc. are included in the packages (Eskom, 1992:18).

However, there is not the same appreciation for the affordability threshold/entry fee gap at earlier stages in the energy transition, or if there is, not much is being done to bridge it. The result is that seemingly low-cost, fuel-efficient appliances, particularly wood stoves, have a very low take-up rate.

(d) *The efficiency of energy use*

Here the focus is on energy-use efficiency or thermal efficiency in the domestic sector, i.e. what proportion of nett energy received by households is actually usefully used? Obviously, efficiency at all stages in the various energy cycles is important to welfare. Greater efficiency in the mobilisation, conversion, distribution/transmission and use of energy sources means resources are utilised more effectively and productively, which has both cost/economic benefits and environmental benefits. The importance of conserving energy, which in effect increases energy-use efficiency, was discussed in section 7.2.

Data on energy-use efficiencies used in the literature and in this study were presented in table 4.2. This information is very important in analysing the impact energy use has on welfare. In the foregoing sections it has been used to calculate useful energy consumption levels and useful energy costs which, apart from being indicators in their own right, have also been used to identify energy poverty and been shown to influence people's energy choices.

The efficiency ratings given in table 4.1 may be assumed to reflect the level of energy-use efficiency at different stages of the domestic energy transition process. While the given efficiencies probably reflect broad trends fairly accurately, there is still scope for improving energy efficiencies at each stage of the energy transition process. In this regard, table 5.2 indicated the extent of improvements that may be feasible.

Whether households improve their energy-use efficiency by using more efficient energy sources or by using their present energy sources more effectively or simply by conserving energy overall, the impact on their welfare is largely the same. Improvements in efficiency means that less energy is used to provide the same or a similar service. Less energy, therefore, needs to be bought, which saves income. The gain in welfare may also be reflected by a decline in the useful energy cost. Where households are reliant on energy sources they gather themselves, greater efficiency would reduce the amount of time and effort they devote to this task. Women would be the main beneficiaries since they are invariably responsible for gathering fuel. This, no doubt, explains why women use fuelwood more sparingly than men (Gandar, 1984:4). Lastly, many energy conservation measures help to improve the amenity of the home environment. For instance, the use of efficient wood/coal stoves reduces indoor air pollution.

6.2.2 The stability goal

(a) *Reliability of energy supply*

Most uses of energy are time dependent, so energy sources must be continuously available, otherwise welfare enhancing opportunities will be lost. Reliability of supply is an indicator of how trustworthy and secure an energy source is. It may be measured by the number of times the supply of a particular energy carrier is interrupted in a particular time period. Another dimension of reliability is that the long term supply of the energy source should be sufficiently certain or secure to warrant investment decisions being based upon it. For instance, it is hardly worth buying paraffin appliances if the supply of paraffin is likely to be restricted for whatever reason.

The reliability of an energy source must be distinguished from the reliability of the appliances in which it is used. If an appliance malfunctions it most certainly affects household welfare. Sometimes the impact can be very great, as when a fire is caused by an electrical fault, or when someone is injured or killed by a primus stove or gas appliance exploding. But these impacts are not to be confused with the consequences of interruptions in the supply of an energy source.

There is no standardised means of measuring the reliability of different energy sources, which makes comparisons across the domestic energy transition process difficult. Cuts in electricity supply are most noticeable, but may not be more numerous than the times the gas or paraffin distribution networks fail to get these energy sources through to consumers. There may be regional differences due to the nature of the supply network, the weather or farming practices. Lightning, cane burning, veld fires and birds can all force electric transmission lines to trip, which interrupts supply.

A reliable supply of energy tends to enhance welfare by creating a sense of security or peace of mind. It is also convenient. The effects of an unreliable supply of energy on welfare are more easily specified. A household may be likened to a continuous processing plant - any interruption of the power supply disrupts the household routine. Welfare enhancing activities that would normally be performed at specific times have to be postponed or foregone: supper is late, the meal is uncooked, the morning shower is cold, the favourite television programme has to be issed, etc. A reliable energy supply is particularly important during very cold weather, since the need for warmth is one of the most immediate needs there is. The lack of spa e heating at the time when it is needed causes severe discomfort and may even result in death.

If households' major source of energy is unreliable, they will tend to make provision by investing in parallel energy systems. In a survey in the Mariannhill area, Rivett-Carnac (1990:29) found that 30% of households with access to electricity had a back-up cooking facility because of the high frequency of electric power cuts. At the other end of the transition process, Eberhard and Dickson (1991:27) found that 87% of rural households in the former Bophuthatswana periodically ran out of fuelwood and had to rely on other energy sources instead. Investing in such parallel systems uses up income that could be used meaningfully elsewhere.

In the case of electricity, an unreliable supply increases the risk of people electrocuting themselves due to uncertainty about whether the power is on or not. The quality of supply is also important since so-called low-frequency incidents or brown-outs affect the operation of many appliances and can even damage them. Eskom (1992:34-35) has an elaborate control network to ensure a consistent quality of supply and claims that the number of interruptions and low-frequency incidents have been reduced "tenfold" since the early 1980's.

(b) *Stability of energy and appliance prices*

Stable prices promote economic certainty, which enables households to plan capital investments and recurring expenditures effectively, even for long periods in advance. Such planning leads to the optimal use of income and enhances household welfare. By contrast, unstable energy and appliance prices is likely to introduce greater risks and uncertainty into household decisions, which means that income is used less effectively. Rising energy and appliance prices also reduces household purchasing power if there are not comparable increases in their incomes. Such inflation may distort expenditure patterns as well. For example, if the real price of energy increases this will lead to a decrease in the consumption of energy and/or a decrease in the consumption of other goods. Either way household welfare is affected negatively.

A detailed examination of changes in energy and appliance prices is beyond the scope of this study. Much of the macro level data on energy prices can be found in South African Energy Statistics, 1950 - 1990 (NEC, 1990). The price increases of coal, paraffin and electricity, on average, exceeded the inflation index (assumed to be derived from the CPI) over the period 1965 - 1989. "In general, price adjustments were smaller than the inflation index up to 1972 ... [but] exceeded the inflation index considerably in the period [illegible] - 1977 and 1980 - 1982.

Since 1983 price increases were held below the inflation index" (Doppegieter *et al.*, 1991:298). However, since 1989 there have been considerable price increases again. The retail prices of the different energy sources have tended to move in sympathy, but the difference between the wholesale price of coal and that of electricity has been decreasing, especially since 1984. (Doppegieter *et al.*, 1991.298).

When assessing the welfare impact of rising energy prices, a distinction should be drawn between increases resulting from inflation and increases that either reflect the growing scarcity of certain energy resources, or the internalisation of externality costs that were previously borne by society as a whole. In the latter instance it is immaterial whether the external costs are internalised by means of a Pigouvian tax or increases in production costs due to the use of cleaning equipment; what is important is that the new price reflects the actual cost of the energy more accurately. If prices rise due to increasing scarcity and the internalising of external costs, individual households would be negatively affected, but the overall welfare effect is most likely to be positive, since these changes will improve the accuracy with which prices reflect the true scarcity value of resources and the social cost of utilising them. Accurate prices promote better planning and the more efficient and effective use of resources, which in turn improve social welfare.

(c) *Provision of physical security*

Few households still keep the fire burning all night in order to ward off marauding beasts due to the widespread decimation of wildlife and changing circumstances. But households still use energy to protect themselves and their property from danger. Eberhard (1986) reports that some rural households light their homes all night "because they are afraid of evil spirits or tsotsis". Lighting is the only energy reliant security measure available to most households in the rural and early urban stages of the energy transition. Access to electricity, however, increases people's options immensely. There is a wide range of electronic security devices available: lighting systems, burglar alarms, closed-circuit cameras, automatic locks, intercom systems, security gates and doors, telephones and two-way radios, as well as smoke detectors, fire alarms and automatic sprinkler systems.

The amount of welfare that households derive from the use of such devices differs from one to the next depending on their characteristics, attitudes and beliefs. People that feel threatened, or are risk averse or wealthy people are likely to derive a greater sense of welfare the more security devices they use. By contrast, people that are not frightened by circumstances, are not bound by their possessions or believe their security is in God's hands are likely to invest less in security devices and may, in fact, feel such devices detract from their sense of welfare.

A "generally acceptable" level of investment/expenditure on security measures does not seem to exist. However, excessive security, which may be characterised by six foot walls, security gates and intercom systems, harms (or at least does not encourage) neighbourly relations and the sense of community and, hence, may detract from welfare. Whether these aspects outweigh the welfare benefits derived from the possession of security devices can only be subjectively assessed. It is therefore not possible to specify any trend in the welfare households derive from using energy for the provision of security. It is, nevertheless, a fact that households in the late stages of the urban energy transition, i.e. those with access to electricity, possess more energy reliant security devices than households at any previous stage in the energy transition.

6.2.3 The distribution and equity goal

(a) *Government policies and access to energy*

The immense economic and political power wielded by whites in South Africa for many decades enabled them to control resources, either directly or through government policy, to their advantage. Part of this process is reflected in the unequal access to energy resources, particularly electricity:

- Eskom has sufficient generating capacity to supply everyone in South Africa with electricity, but almost 70% or approximately 23 million people living in 3 million households do not have access to it (Du Plessis, 1992:1).
- Virtually all whites, even those in remote rural areas, have access to electricity, while only 15% of 20% of blacks have electricity in their homes (Theron, 1992:10).
- About 20% to 30% of blacks living in urban areas (including small towns) have access to electricity. In the former homeland areas it is available to only 5-10% of the population, while on farms owned by whites about 15% of the workers have access (Theron, 1992:10).

These racial and spatial disparities are compounded further by differences in service quality. The former white municipalities have over the years developed electricity supply networks that are reliable, safe and cost-effective. In addition, because the large proportion of their networks have already been paid for, they were able to use the profits generated from the sale of electricity to subsidise the rates of the predominantly white property owners in their areas and to finance the provision of non-income generating services such as roads, sewerage, refuse removal and parks (Stavrou, 1992:3). In 1989 white municipalities made a total profit of around R600 million from the sale of electricity (Theron, 1992:11).

By contrast, electricity supply to township areas by the now defunct Black Local Authorities (BLAs) was, in most instances, in a state of chaos. BLAs were administratively weak. They were, therefore, incapable of maintaining (let alone expanding) the networks under their control or of ensuring accurate meter reading and billing. BLAs were also politically unpopular, consequently consumers boycotted paying for services. This crippled BLAs financially, particularly in the former Transvaal. In some instances they were unable to pay their bulk suppliers of electricity (often the local white municipality) and as result had their supply cut off (Stavrou, 1992:4).

From the inception of the electricity industry in South Africa, access has been skewed to favour whites. It would appear that prior to 1948 the inequalities were largely a by-product of the racist patterns of settlement and development that took place. There does not seem to have been any deliberate or systematic policy to deny blacks access, but neither was there any attempt to include them. Their interests were neglected or, most probably, ignored. After 1948 the plethora of racist government policies entrenched and aggravated these inequalities:

- Spending on social services, which included electrification, was deliberately skewed to favour whites. The government made a concerted effort to electrify white communities and farmsteads. In the process a significant precedent was set: the capital investment costs were not borne by the newcomers, but by all the consumers on the national grid (Stavrou, 1992:5).
- Within the migrancy-apartheid scheme black township dwellers were regarded as 'temporary sojourners' and so their needs were deliberately ignored. It was hoped that by denying townships access to basic services, blacks would be 'encouraged' to move to or stay in the homelands.
- The Group Areas policies divided along racial lines towns and cities that should have been regarded as single entities and served by single municipalities, as now is the case. The resulting white municipalities had access to greater financial resources, as well as administrative capacity, than the equivalent bodies in the black areas. Some of the consequences of this imbalance have been noted already. Another, very important result was that any form of cross-subsidisation between rich (white) ratepayers and poor (black) ratepayers was eliminated. The concept of 'one city one tax base' was suppressed.
- Eskom, as a parastatal, fell within the governments sphere of control. Its policies, in the past, followed the government line. Specific examples of this are the establishment of 'independent' electricity supply commissions in the former homeland and TBVC areas and the fact that BLAs in most instances had to purchase electricity from white municipalities and not direct from Eskom.

Changes on the political front have already begun to affect the electricity supply industry. The new government is under pressure from black urban communities to deliver universal urban electrification. Eskom is tackling the task under the slogan "Electricity for all". Areas that are already receiving attention include:

- the composition of the Electricity Council and the need to bring decision making regarding electricity closer to the communities that were excluded [illegible]
- the fragmented nature of local supply structures, particularly in so far as they are in conflict with the concept of 'one city one tax base' and in so far as they are not cost effective;
- the structure of the electricity tariffs and the possibility of using them to recover capital expenditure and for cross-subsidisation;
- resolving payment boycotts;
- the financing of extensions to the supply network; and
- the development of cost-effective delivery systems, e.g. readi-boards and pre-paid meter systems.

Eskom and some municipalities are deeply involved in projects to electrify townships, but as yet the government has only committed itself to universal electrification in principle, but not to any sort of electrification plan. How soon it will adopt such a plan depends on political processes related to resolving differences surrounding the first four issues mentioned above, namely representation on the Electricity Council, unification of urban municipalities, the specification and implementation of an appropriate electricity tariff structure and the non-payment of electricity bills. More practical issues such as financing, appropriate delivery systems and the technical capacity to implement large-scale electrification programmes are unlikely to hold up the process (Van der Berg and Du Toit, 1991:29-23). Assuming there are no major hitches, an electrification programme would still take at least 20 years and financing of about R800 million per year from government to reach all households in South Africa (Theron, 1992:17). Such a scenario is, however, sensitive to the priority given to electrification *vis-à-vis* other social services. Van der Berg and Du Toit (1991:21-27) investigated different scenarios of housing and electrification in urban areas. They found that under the most likely scenario it will take 20 years to increase the incidence of access to electricity to 76% among urban households. Clearly, eradicating inequalities in access to electricity is not going to be easy or costless.

Government policies have not only limited access to electricity, but have also affected people's access to other energy sources, particularly fuelwood. Policies such as the pass laws, influx control and resettlement programmes which aimed to limit or even reverse the process of black urbanisation had particularly profound effects. They led to an artificial increase in homeland populations, which put additional pressure on already overburdened natural resources. As a result, fuelwood availability has decreased drastically in many areas. The use of dung and crop wastes, the commercialisation of fuelwood and the low levels of fuelwood consumption compared to those of paraffin and gas all serve to confirm this trend. Examples cited by Wilson and Ramphele (1989:45) show that resettlement areas such as Qwa Qwa, Amatelang and Bendell in Bophuthatswana and Thornhill in the Ciskei suffer very severe energy shortages because the environments in these areas are not able to support the high numbers of people forced to settle in them. The situation in the former homelands was further aggravated by past governments' policy of neglecting these areas. Even now, despite the obvious fuelwood crisis, the new government has been slow to act. Afforestation, woodlot, stove and hotbox programmes in rural areas are still only being undertaken by NGOs. The new government needs to be sensitive to the needs of those in the rural areas, and not only the urbanites who have greater political clout.

(b) *Lack of credit for the purchase of appliances*

The normal functioning of the market tends to accentuate and perpetuate inequalities in access to the benefits of certain energy sources and appliances. Access to credit, in whatever form, is usually linked to a household's financial position (household income and fixed assets). Wealthier households are, therefore, able to purchase appliances on credit and so increase the benefits they derive from energy, while poor households are denied access to credit because their low incomes make them a poor risk. This is an example of how institutional structures make it difficult for poor households to break out of the poverty trap. Poor households probably have a greater need for credit than rich households since their incomes do not give them much scope to alter their consumption patterns. The greatest portion of their income, if not all of it, is used up in satisfying basic needs, consequently they are unable to purchase even seemingly inexpensive appliances. They also cannot afford to make the initial investment in a new energy system even though it may reduce their current expenditure on energy (section 3.2.4). The experience with improved wood stoves and hotboxes is relevant in this regard (EDRC, 1992:29; Gandar, 1988:11). In both instances ownership of the appliances would benefit household welfare, but the target households could not afford them, even though the prices were modest.

Stokvels and other informal credit arrangements have emerged in order to meet poor households' needs for credit. However, these forms of credit are more expensive than credit in the formal sector. Poor households, thus, have to pay more for credit than rich households, which does nothing to alleviate the maldistribution of benefits and opportunities between rich and poor.

The lack of credit is most noticeable in the final stage of the urban energy transition, when households are wanting to electrify. Connecting a household to the national grid costs upwards of R2300 (the readi-board or pre-paid meter cost R300 and the connection and installation R2000 plus) (April 1992) (Stavrou, 1992:6). This does not even include the cost of appliances needed to use the electricity. These capital costs or entry fees represent a substantial barrier to poor households. Eskom and some municipalities have recognised this and introduced schemes whereby they bear the installation cost initially with only a nominal fee being levied for the hook-up. The shortfall is then recovered via a surcharge on the household's electricity consumption. The so called "S-1" tariff is used for this purpose (Stavrou, 1992:5). Eskom has also started a system of cross-subsidisation whereby all consumers on the grid contribute towards the cost of grid extensions.

The main advantage of these schemes is that they give a *de facto* long term loan to households for the purpose of installing electricity. Furthermore, they link repayment of the loan to the amount of electricity the household consumes. Thus, the rate of repayment is partially linked to households' ability to pay. The system seems to work so long as the newly connected households utilise electricity for energy intensive tasks such as cooking and water heating. To encourage electricity use, Eskom sometimes offers stoves, irons and heaters in the electrification package subject to the same repayment conditions. Despite these good points, the S-1 tariff approach represents a departure from previous policy. As already noted, when white communities and farmsteads were being electrified, the capital costs were borne by all consumers on the grid. Van der Berg and Du Toit (1991:31) argue that if the cost of all new electricity connections were borne by all consumers there would be "some upward pressure on electricity tariffs", but the overall effect "would be less than a rise of one quarter of a percentage point in the VAT rate". Such a policy also has the advantage of being a hidden tax on the rich, while providing explicit benefits to the poor.

The efforts made to overcome the lack of credit where electrification is concerned, however, do not address the credit needs of households who are either too poor to afford electricity or are unlikely to get access to electricity because they live in rural areas. Other schemes to enable these households to overcome the 'entry fee' barriers that face them at different points in the energy transition process are needed.

(c) *The incidence of energy subsidies*

The literature on domestic energy use in South Africa that was reviewed for this study did not mention the possibility of subsidising energy sources in order to assist poor households. Thus far, no such policy has been implemented. This probably, in part, reflects past governments' lack of concern for the poor. Given the new government's greater interest in social welfare it is important to know whether, say, a paraffin subsidy would be an efficient and effective means of assisting those suffering from energy poverty.

To start with, there are well known welfare arguments indicating that a lump sum subsidy enables households to attain higher levels of utility than a subsidy of equivalent value on a specific good, because the latter skews the household's consumption in favour of the subsidised good, while the lump sum subsidy enables the household to allocate its income according to its consumer preferences. The extent of this difference in welfare is, however, uncertain and whatever welfare losses there may be would probably be more than compensated for by the fact that a specific subsidy is far easier and cheaper to administrate than an income subsidy. It may also be argued that a specific subsidy such as one on paraffin, targets the poor effectively since paraffin is used almost exclusively by poor households. This is true, but those that need assistance most would benefit least since they would still not be able to afford sufficient paraffin to meet their needs, even with a subsidy. Those that can already afford to use paraffin extensively would tend to benefit most. Another disadvantage of such a subsidy is that it would encourage the continued use of paraffin by households that would normally have progressed to using cleaner energy sources such as gas and electricity. In addition, if the subsidy is large, people may be tempted to use paraffin in their vehicles, thus defeating the aim of the subsidy altogether.

As regards electricity, domestic consumers do not receive any explicit consumption subsidy. Indeed, Eskom's new tariff structure favours large consumers, thus discriminating against households in general (Stavrou, 1992:8). Nevertheless, the government has in the past made substantial capital investments in electricity generation and distribution infrastructure. There are cogent public goods arguments justifying these investments, but they do not detract from the fact that electricity is in effect subsidised and that the benefits of this subsidy accrue almost entirely to the consumers of electricity, who, as noted previously, are predominantly urbanised and/or white. The unequal incidence of these benefits strengthens the arguments for continued government involvement in the financing of electrification projects and the cross-subsidisation of these projects by all consumers on the grid.

In the past white households also benefited from what may be termed the 'load management subsidy'. Most of the former white municipalities supplied electricity to a broad range of consumers: light and heavy industries, commercial enterprises and households. This enabled them to purchase bulk electricity from Eskom at competitive rates and to institute cost saving load management measures (e.g. regulating the times at which geysers are switched on). The former white municipalities also served a wide range of electricity users (domestic, industrial and commercial) that enabled them to maintain higher basic load levels and thus lower peaks in demand. (Eskom charges municipalities for the peak level of energy consumption during a particular time period.) By contrast, the former BLAs generally only supplied households which meant lower bulk, less scope for load management and more pronounced peaks in demand. The electricity available to black households was (and in many instances still is) therefore more expensive than that available to white households. The inequality was aggravated further by the fact that many BLAs had to purchase their electricity from white municipalities instead of directly from Eskom (Stavrou, 1992:7). The benefits of this load management subsidy will be more evenly spread now that towns and cities are integrated on the principle of "one city, one tax base" or if Eskom supplies all consumers directly. The former solution is the more practical solution, given the existing structure of local electricity distribution networks. In some instances it may be to the consumer's benefit to have Eskom administer and supply electricity directly to them either because there is no viable local authority to undertake the task or because there are historical conflicts between communities that need to be resolved before the amalgamation of service functions can be organised.

At a completely different level, certain sectors of society, particularly future generations, are subsidising part of the cost of consuming energy. The extent of this subsidy is equal to the difference between the marginal social cost and the marginal private cost (or the consumer price) of energy sources consumers use. Stated differently, the subsidy is equal to the public or external cost of air pollution, global warming, deforestation, water pollution, nuclear waste, resource depletion and general environmental degradation resulting from domestic energy use. As regards the incidence of this 'subsidy', it may be argued that since affluent households generally consume more energy per capita than poor households, they derive greater benefit from the subsidy. The fact that affluent households use mostly electricity also means they tend to be spatially separated from the external effects of electricity generation. Most households using electricity do not suffer from the pollution on the Mpumalanga Highveld which is caused in part by the power stations located in the area. Chapter 5 discusses the incidence of most of the external effects resulting from energy production and use. Suggestions are also made as to how these externalities might be either limited or internalised so that all consumers pay the true (private plus social) cost of the energy sources they use.

6.2.4 The civilisation goal

(a) *Possession of appliances*

As noted above, many aspects of energy use may be relevant to the attainment of more than one of the intermediate goals of welfare. The possession of appliances is a case in point: it affects both the growth and efficiency goal and the equity goal. Indeed, the discussions and data on appliance ownership in the literature reviewed for this study are directed towards either establishing the level of material well-being within groups or assessing racial and rural-urban inequalities. However, these aspects represent only one side of appliance ownership - a side that is largely based on the assumption that the possession of material goods is positively correlated to household welfare. The validity of this assumption is not being questioned here; yet it does not take cognisance of the fact that a far greater proportion of the welfare households derive from appliances arises from their use rather than from their mere possession. This section, therefore, emphasises the services that households derive from appliances, as well as the links between these services and the intermediate welfare goal of "civilisation". These links arise from the assumption that the services derived from appliances are integral to modern life-styles. But first data on appliance ownership in township and peri-urban areas in KwaZulu-Natal and in the Western Cape are presented and discussed.

Table 6.9: Appliances owned by households in township and peri-urban areas in Mariannhill, Natal

Appliance	% of households with appliances	
	Electrified	Non electrified
Electric stove	92	-
Paraffin stove	44	90
Gas stove	40	33
Coal stove	-	11
Open fire	-	17
Lighting	see note 1	see note 2
Irons	see note 3	see note 3
Electric refrigerator	92	-
Paraffin & gas refrigerators	-	15
Electric heaters	48	see note 4
Water geyser	27	-
Radio	see note 5	see note 5
Hifi	46	see note 5
Television	79	see note 5

Source: Rivett-Carnac, 1990:29-43

Notes:
1. Universal use of electrical lighting may be assumed.
2. The use of paraffin and of gas lamps was found to be limited while the use of candles was "almost universal" (Rivett-Carnac, 1990:34).
3. "The iron is almost universally used; where mains electricity is available, most people own electric irons. In non-electrified households irons are usually heated on the stove" (Rivett-Carnac, 1990:42)
4. Few non-electrified households in this area own space heating appliances due to the mild climate on the Durban area (Rivett-Carnac, 1990:34).
5. "Over the entire sample more than three quarters owned radios, half owned television's and a third hifi equipment" (Rivett-Carnac, 1990:39).

Table 6.10: Distribution of appliances among black households in the Western Cape

Appliance	% of Households with appliances
Stoves	100
Lighting	100
Iron	74
Heater	57
Radio	52
Hifi/tape deck	35
Television	33
Refrigerator	20

Source: Viljoen, 1990:114

Table 6.11: The type of appliances owned by black households in the Western Cape

Energy source	Percent of households with each type of appliance						
	Stove	Lamps/lights	Heater	Fridge	Radio	Hifi	Television
Electricity	15.0	20.7	6.1	17.2	5.6	12.2	17.8
Paraffin	52.2	43.3	49.4	0	-	-	-
Gas	8.3	1.1	2.7	2.8	-	-	-
Electricity & paraffin	2.7	-	-	-	-	-	-
Electricity & gas	3.3	-	-	-	-	-	-
Paraffin & gas	18.3	-	-	-	-	-	-
Candle	-	7.8	-	-	-	-	-
Candle & paraffin	-	26.8	-	-	-	-	-
Wet cell batteries	-	-	-	-	2.2	-	15.0
Dry cell batteries	-	-	-	-	43.9	-	-

Source: Viljoen, 1990:114
Note: Only 17.8% of these households are electrified.

Despite differences in the format in which information is presented in tables 6.10 and 6.11, it is evident that appliance ownership among households in the township and peri-urban areas of KwaZulu-Natal and the Western Cape is in many respects similar. In both areas the ownership of cooking and lighting appliances appears to be universal, the use of irons is widespread and there are high levels of radio, television and hifi ownership. Another similarity that is not quite as obvious is that nearly all electrified households in each sample own both electric stoves and refrigerators. To what extent these similarities are characteristic of appliance ownership in other township and peri-urban areas in South Africa is not known, but there seems no particular reason why they should differ greatly from these areas.

Of greater interest are the differences between the KwaZulu-Natal and Western Cape samples and what may be inferred from these differences about appliance ownership patterns in other areas. Most obvious is the total absence of any mention of coal stoves and open fires in the Western Cape sample. The reason for this is apparent in table 4.10, where it is noted that just 1.7% of the households sampled use fuelwood and none use coal. By contrast, in the Mariannhill area of KwaZulu-Natal 11% and 17% of non-electrified households have coal stoves and open fire places respectively, which compares favourably with the levels of coal and fuelwood usage reported in table 4.10; between 9.4% and 13.6% use coal and between 15% and 31% use fuelwood. It therefore appears that the ownership of stoves is dependent on the main energy sources households have access to and use. There is also a difference in the ownership levels of space heating appliances between the samples. In the Western Cape, 57% of the households own heaters, while in the Mariannhill area 64% of the households "employ no form of space heating for warming their homes" (Rivett-Carnac, 1990:39). The mild climate in the Durban area is atypical in South Africa, consequently patterns of heater ownership across the country are more likely to be similar to those found in the Western Cape rather than

Mariannhill. Another difference between the samples relates to the level of back-up cooking systems among electrified households that own electric stoves. In the Western Cape fewer than a third of the households with electric stoves own parallel gas or paraffin systems, while in the Mariannhill area 80% had a back-up cooking facility - "because of the high frequency with which ... black-outs occur" (Rivett-Carnac, 1990:29).

This discussion of the similarities and differences between the data sets prompts the question: what factors affect patterns of appliance ownership? Some of the factors are referred to briefly below:

- the need for a particular service. This explains the universal ownership of appliances like pots, stoves and lights;
- the type of energy sources households have access to and use, as well as the versatility and reliability of these energy sources;
- the household's level of income, the cost of appliances and the availability of credit to purchase appliances. These factors were discussed in sections 6.2.1(c) and 6.2.3(b), where it was noted that the price of appliances constitutes an 'entry fee', which if greater than the 'affordability threshold' of the households would exclude them from gaining access to the services of the particular appliance (or energy source) unless credit were available to them. It was also noted that the availability of credit favours those with higher incomes;
- the length of time a household has had access to an energy source, particularly electricity. It takes time to build up a stock of appliances; and
- the host of subjective factors such as perceived need, taste, convenience, time saving, keeping up with the neighbours, etc.

How does the possession of appliances affect household welfare?

Various links may be identified: in the introduction to this section it was suggested that the services that households derive from appliances they own are the principal link. Households own stoves, lights, geysers and irons for cooking, lighting, heating water and ironing. Obviously the nature of the service and its contribution to household welfare varies from appliance to appliance and according to the situation of the particular households. Nevertheless there are four broad categories of services worth noting:

(i) Services arising from the use of 'key' appliances which include pots, stoves (apart from wood and coal stoves), most lamps and lights, refrigerators and nearly all electric appliances. Households would not be able to benefit from these services without actually owning or having access to the appropriate appliances. For instance, a household with access to electricity requires access to a variety of electric appliances as well, otherwise it will continue to be excluded from the welfare enhancing potential of this energy source. The appliances are the key to using the energy sources to supply services that add to household welfare. This is why the cost of appliances is referred to as an 'entry fee' which households must pay in order to progress from using one energy source to another and from one phase to the next in the domestic energy transition process.

(ii) Services that are unique to particular appliances and that cannot be substituted or obtained by other means. For example, the services derived from audio-visual appliances fall into this category, while the services of washing machines, vacuum cleaners and cake mixers do not, since the tasks that these appliances perform can be done manually. The high levels of radio and television ownership noted in the above tables suggests that these unique services are important to households and contribute significantly to their welfare.

(iii) Services that enhance the welfare derived from certain uses of energy, even though the appliance is non-essential. The services of wood and coal stoves are typical examples: a household can cook quite adequately over an open fire, but a stove offers distinct advantages such as smoke removal, simultaneous water heating and fuel saving. The use of the appliance improves the quality and convenience of the particular energy service. Other appliances that provide this category of service include paraffin pressure lamps, geysers, microwave ovens, pressure cookers and kettles.

(iv) Services that 'make life easier' by simplifying tasks, saving time or improving hygiene. Washing machines, vacuum cleaners and polishers, dish washers, hair dryers, all manner of electrical kitchen and do-it-yourself appliances, lawn mowers and even burglar alarm systems all deliver services in this category. The use of these appliances contributes to household welfare in at least two ways: firstly, the tasks they are used to perform contribute to the smooth functioning of the household and, secondly, the appliances enable the tasks to be accomplished more quickly and efficiently, to a higher standard and with less effort. These aspects are probably more important to welfare, since the actual tasks would anyway have had to be done by other means if appliances were not used.

These service categories do not by any means cover all the welfare enhancing opportunities that appliance ownership afford. One of the most important aspects not referred to above is the prestige value of owning certain appliances or particular makes/brands of appliances. This contribution to household welfare is difficult to assess, but in some cases can actually determine whether a household decides to invest in a particular appliance or not.

Overall, the role appliances play in facilitating a modern life-style is enormous. Indeed certain appliances are symbols of modernity, e.g. television and refrigerators. However, appliances are also often seen as symbols of the 'culture of waste' and of the consumerist ethic that characterises modern life-styles. Both these perspectives have validity; however, to draw a line between what appears to be a reasonable level of appliance ownership and what is excessive is difficult. Most non-electrical appliances (e.g. wood stoves) enhance household welfare while at the same time improving energy-use efficiency, therefore ownership of these appliances should be encouraged. Ownership of electrical appliances that provide essential services should also be encouraged. It is when one gets to appliances that provide services of the kind noted in category (iv), i.e. services that simplify tasks, save time or improve hygiene, that one runs into difficulties as to what is desirable from a "civilisation" perspective and what is excessive from an environmental perspective. Appliances of purely a prestige nature and the multiple ownership of appliances like televisions fall on the consumerist side of the line, which damages the environment more than it promotes 'civilisation'. There is thus a trade-off between a modern consumerist life-style and the environment.

Nevertheless there is scope for increasing many households' level of appliance ownership before they even begin to approach the levels of excessive consumerism characteristic of many more wealthy households in South Africa. It is desirable both in terms of promoting 'civilisation' and creating a more egalitarian, stable and just society that the former households' level of appliance ownership be raised. Ways of facilitating access to appliances are discussed in section 7.1.3(c).

(b) *Lighting*

Households do not use energy to supply lighting with the express purpose of achieving the intermediate goal of civilisation. The effect of lighting on this goal is better described as a positive externality.

Numerous aspects of lighting are relevant to household welfare. The cost of candles, lighting appliances and energy sources used in these appliances, the quality of lighting supplied by different sources, and the convenience and risk aspects of each lighting source are all important. However, the impact of lighting on the civilisation goal has more to do with how households use lighting or what they do given the availability of lighting.

The most obvious use, indeed the primary purpose, of using energy to supply lighting is to extend the day into the night, i.e. to enable people to continue day time activities after the sun has set. The quality and convenience of the lighting source, and in some cases the price as well, are key determinants in this 'substitution' process. Cheaper, more convenient and better quality lighting sources are likely to be used more extensively. On these criteria electric lighting is far superior to any other source of lighting and is consequently perceived as the best and preferred source of lighting. As Rivett-Carnac (1990:33) notes, non-electrified households only use candles and paraffin for lighting by necessity and not by choice. When households are electrified, access to high quality, convenient lighting is one of the main benefits.

Using electric lighting to extend activity times means that household members, particularly scholars and students, are able to spend more time reading and studying, which has a direct impact on literacy and overall educational standards and, hence, on the civilisation goal. Obviously necessity dictates that other forms of lighting are also used for these purposes, but their poorer quality discourages extensive use.

Other uses of lighting that enhance households' quality of life include the provision of security, the performance of household tasks after day light hours and the facility of being able to work after hours to earn extra income. Linked to these is the convenience of not having to make early morning starts in the dark and being able to see one's way around when coming home late at night - especially important for shift workers. Lighting also facilitates night time entertainment and social occasions. Again, the convenience, quality and low risk of electric lighting mean that households with access to it generally enjoy higher levels of benefit in the performance of all these tasks than households using other forms of lighting. Ways of improving household access to lighting services are discussed in section 7.1.4(b).

(c) *Entertainment opportunities*

The use of energy facilitates home entertainment in at least three distinct, but by no means separable, ways: households use energy in appliances that enable them to 'create' more leisure time; energy is used to create a context for the entertainment, e.g. an evening around a fire or a dinner by candle light; and energy is used to power the appliances that provide the entertainment, e.g. radio, television or video-machine.

(i) *Creation of leisure time* The creation of leisure time and the value of leisure time are important topics in microeconomics (see Bryant, 1990: 122-140). Essentially, households treat leisure like any other scarce commodity, i.e. they seek to increase their consumption of it until the marginal rate of substitution of leisure time (MRS_L) is equal to the marginal rate of substitution of work time (MRS_W) or, for that matter, of all other commodities (MRS_X). In effect this means households, in order to increase their leisure time, exchange work time (and the income associated therewith) and the income earning opportunities missed during the leisure time, as well as the income spent on entertainment activities pursued during the leisure time, for it. An additional cost of leisure time is the price of 'time saving' appliances that are supposed to enable households to create more leisure time by simplifying and speeding up the performance of many household tasks. That there is a substitution effect between income used to purchase such appliances and leisure time is obvious, but it is impossible to specify what percentage of the appliance price should be designated as part of the overall cost of leisure time. It will vary for each household. One must also not forget that these appliances provide other services to the household in addition to helping create leisure time.

All manner of appliances are designed to help in the creation of leisure time. Many are hand operated and so fall outside the scope of this discussion. Of the remainder most, indeed nearly all, rely on electricity; they include microwave ovens, vacuum cleaners, polishers, geysers, hair dryers, washing machines, dish washers, electric kettles and toasters, cake mixers and all manner of kitchen choppers, slicers and liquidisers, as well as a host of do-it-yourself appliances.

Households in the rural energy transition and the early phases of the urban energy transition have very little scope to use energy operated appliances to create leisure time. Firstly, appropriate appliances using the energy sources they rely on do not exist and, secondly, even if they did exist, most households in these energy transition phases would not have been able to afford them. Most newly electrified households are also excluded from the time saving benefits of many appliances, since their incomes are such that they cannot afford them. Therefore only households with access to electricity and with high incomes are really able to take advantage of these time saving services. Consequently it may be concluded that households' position in the domestic energy transition process, along with their level of income, is an important determinant of the amount of leisure time they are able to 'create' through the use of time saving appliances; hence also of the amount of welfare they are able to derive from the enjoyment of leisure time.

(ii) *Context for entertainment* Many households use energy sources to provide an appropriate context, milieu or atmosphere for the enjoyment of leisure time or for the pursuit of entertainment. The most important use of energy in this regard is in the provision of lighting. Households use all forms of energy for this purpose: the open fire forms a social centre or context for fellowship, story telling, reminiscing and romance wherever it is found; candles are almost essential ingredients of romantic evenings or times of celebration; and other forms of lighting, especially electric lighting, enable a host of entertainment activities from board games to bridge, from dancing to darts, to be continued long after the sun has set. Throughout the domestic energy transition, energy is used to provide lighting for these purposes. This is also one of the areas of energy use where there are no clear boundaries between the different transition phases. Candle light dinners are nearly a universal phenomenon, and households reliant on fuelwood do not by any means have a monopoly on the use of hearth fires to provide social centres on cold winter's nights.

Another common use of energy in the creation of the context or atmosphere for the use of leisure time is in the provision of background music (as opposed to the music being the focus of the entertainment). Hifi's, radios, CD players, etc. all provide this service and to operate these appliances the household obviously either has to have access to the electric grid or to wet/dry cell batteries. The widespread use of the latter amongst non-electrified households suggest that this service is valued by many of them.

Energy is also used to regulate the temperature of indoor environments, which in so far as it is not essential for survival may be regarded as creating a pleasant context for living, which naturally includes leisure time.

(iii) *Provision of entertainment* Households use energy sources directly to provide entertainment, e.g. the candles or sparklers on a birthday cake, the fires on a feast day, the lights on a Christmas tree, the bonfires, crackers and all manner of rockets associated with Guy Fawks and the simple fiddling with the wax of a candle. Fuelwood and candles are most often used in this way and so a household's position in the domestic energy transition process seems to play little role in determining access - income is the most important determinant.

Households also use energy sources to operate some appliance which provides an entertainment service. These appliances are nearly all reliant on electricity. Most require access to the grid, while a few such as audio-visual appliances can be operated with batteries. Electrified households are, therefore, in a better position to take advantage of this welfare enhancing form of energy use than other households. This is especially so given the extremely high cost of energy derived from both wet and dry cell batteries compared to the cost of grid electricity. The few cases where entertainment providing appliances do not use electricity are generally related to cooking for fun, e.g. braais, stir fries and fondues, as opposed to cooking out of necessity.

Household income levels also play an important role in determining the range of appliances they can afford. Most households have radios, fewer have cassette players and televisions and still fewer have video machines, CD players, computers and electric musical instruments. The stock of electrically operated toys a household owns is also largely a function of its income rather than its position in the transition process.

The extent to which household welfare is enhanced through the ownership and use of these appliances is significant, but impossible to quantify given their differing characteristics, the way they value particular forms of entertainment, the reality of diminishing returns in the use of these entertainment services and the overall effect these forms of entertainment can have on family life or on individual members (e.g. the negative effects of too many violent television programmes, videos and computer games).

What is clear, however, is that access to electricity, along with the income to purchase certain appliances that provide entertainment services, can enhance household welfare enormously by bringing a whole new range of entertainment opportunities within households' reach.

6.3 Energy use and the subjective measures of welfare

This section examines people's subjective assessment of how energy use affects their welfare position. in other words, how satisfied are they with their pattern of energy use? What pattern of energy use do they aspire to? Does their use of energy and appliances enhance their status position or sense of self worth? These and other similar questions are discussed in the sections below.

People's subjective experience of the level of welfare they enjoy as a result of their energy consumption pattern cannot be treated as a completely separate dimension of welfare. Since it is subjective, this aspect of welfare is influenced by a host of other psychological and normative factors that may be completely unrelated to energy use. Did the person have a good night's rest before the interview or what do people think they can gain by giving answers with a particular bias? These problems are well known in these kinds of studies, consequently great care is usually taken in the formulation of questionnaires, the manner in which the interviews are conducted and in the interpretation of the results. The use of large samples is also aimed to minimise these problems.

People's subjective experience of how energy use affects their level of welfare is also influenced by the objective circumstances of their energy consumption patterns. The type of energy sources available, the quantity of energy used, the advantages and disadvantages of each energy source, the appliances a household has access to, etc. all combine to influence people's feelings with regard to the energy sources they use. Special circumstances of a particular household can also have an important impact. For instance, if people have experienced some mishap, say the explosion of a primus stove, with a particular energy source or appliance, then they will be inclined to regard that energy source or appliance as dangerous - more dangerous than it may in fact be.

Households' subjective estimation of the benefit they derive from the use of energy, therefore, needs to be placed in the correct perspective. From the household point of view their subjective experience is what matters most to them. It is what they experience, it is the way they perceive things, it is what they feel - all of which affects their immediate sense of well-being. However, people's subjective experiences do not and cannot give the whole picture. Some people may be desperately miserable with their lot, but measured objectively their circumstances may not be too bad or could be a lot worse.

People's subjective experiences of the welfare they derive from energy consumption provide insights into how household welfare levels are affected by the use of energy and appliances that are not determinable from the host of objective measures and circumstances discussed elsewhere. But to claim that "the subjective element of quality of life allows us to begin approximating a standard of evaluation" seems to be claiming too much (Møller *et al.*, 1987:4). The status, importance or value one attaches to subjective indicators of people's welfare position remains a normative question. Subjective indicators do not embody the whole truth about people's welfare positions, nor are they a standard or base by which other measures of welfare should be assessed. Instead, they represent one of the windows through which a particular view of the truth may be obtained in the process of building up an integrated picture of how household welfare is affected by energy use and the domestic energy transition process.

(a) *Satisfaction*

Satisfaction implies a sense of contentment or happiness with existing circumstances and an absence of striving to bring about change. Households that are satisfied with their existing patterns of energy use experience a sense of well-being that enhances their overall sense of welfare.

Households' satisfaction with their pattern of energy use is usually founded in the fact that they have access to the energy sources and the range of energy services they desire. In other words their needs and, to a lessor degree, their wants are being met to a sufficient extent to make them content with what they have. Satisfaction implies more than just having nothing to complain about, which is a neutral or indifferent response. It suggests a real sense of well-being with the situation as it is.

Møller *et al.* (1987:44-45) report the results of a survey which measured different race groups' levels of satisfaction in specific domains of living, e.g. health, housing, education, income, etc. Unfortunately, they did not include domestic energy consumption as one of the domains of living which they investigated. This is somewhat strange given that energy is a basic need of some importance.

If it is assumed that groups' level of satisfaction with energy services follows the broad trends identified for the other basic needs it implies, unsurprisingly, that whites and Indians are more satisfied than coloureds with their patterns of domestic energy consumption, while coloureds are more satisfied than blacks. The same ordering is found in respect of "access to government/municipal services" which may be assumed to include the supply of electricity: 80% of whites, 68% of Indians, 55% of coloureds and 33% of blacks perceived themselves to be "satisfied" or "very satisfied" with the services they received (Møller *et al.*, 1987:44-45). To extend the interpretation of these results any further would be reading more into them than can be justified. Nevertheless, previous discussion has shown that black households dominate the rural and early urban phases of the domestic energy transition, coloured households the middle phases of the urban transition and Indians and whites the late phases of the urban transition. It would therefore appear that there is a measure of correlation between households' position in the domestic energy transition process and their level of satisfaction with their circumstances. This would confirm the argument that satisfaction is related to the extent to which needs and wants are fulfilled.

(b) *Aspirations*

Modernisation theories suggest that the picture effect and/or the empathy effect are the driving force behind the diffusion of modern institutions, behaviour and norms. At the individual level these effects enable people to imagine themselves in new, improved positions and create in them a desire to improve their circumstances. In other words they aspire to something better than what they have at present.

In the context of domestic energy use people's aspirations may find expression in the desire for improved availability of energy, the desire for access to more modern energy sources, especially electricity, or to the services of particular appliances, and the desire to possess certain specific appliances. Obviously a host of considerations may underlie these aspirations: expectations, cost, convenience, effectiveness, status value, modernisation, entertainment or envy.

Households' aspirations with regard to their pattern of energy use can affect their welfare positively or negatively. The effect may be negative if that to which they aspire is beyond their means, both present and future, or if it is unobtainable, e.g. grid electricity in remote rural areas. People may become disillusioned, despondent, angry or frustrated by having their aspirations blocked by circumstances beyond their control. These emotions will impact negatively on their sense of well-being.

Aspirations may affect people's welfare position positively if their desire to obtain something leads to striving or to greater motivation that has positive outcomes in that they are able to obtain what they desire, e.g. a television set, access to electricity, etc.

The effect that aspirations have on household welfare at different phases of the domestic energy transition process differs from household to household, depending on their existing circumstances and scope to change them, what they aspire to and many other factors. No link between specific phases in the energy transition process and aspirations can be postulated; there are simply too many variables, in addition to households' objective pattern of energy use, that affect the formation of aspirations.

(c) *Status value*

In this discussion status value is that enjoyment, pleasure or sense of fulfilment that people gain not from the possession or use of something, but from knowing that others are aware or see that they possess it. In other words, in this context status value has purely a materialistic basis. It is closely allied to the idea of conspicuous consumption. This is obviously a gross simplification of reality since status is accorded a person on a host of other criteria as well, e.g. their position, power or personal characteristics.

The status or recognition accorded to people by their friends, associates and community increases their welfare or sense of well-being by raising them up above the rest in some way. Status value enables people to differentiate themselves from others. It increases their sense of individuality or uniqueness which in turn enhances their sense of personal worth. For this reason the quest for status entails striving for an improved position relative to other members of society, which may also give rise to real improvements in material welfare. For example, the desire to keep ahead of the Joneses may cause a person to work overtime in order to be able to buy that new deep freeze. However, as in the case of aspirations, the quest for greater status may be frustrated which may give rise to feelings of failure, disillusionment or despondency. These emotions will impact negatively on people's sense of well-being.

In the area of domestic energy use people may seek to enhance their status by consuming certain fuels and/or owning certain appliances.

Households that have access to or use energy sources that are viewed as better or superior to that commonly used in the community in which they live tend to enjoy a measure of status as a result. So in the early phases of the rural energy transition the use of paraffin or gas or, better still, the use of a stand-alone electric generator may be status symbols among households that can generally only afford to use fuelwood. However, in the later phases of the rural energy transition paraffin will become less of a status symbol as more households will be using it as a matter of course. Access to grid electricity will be the new status symbol. Similarly, in the early phases of the urban energy transition most households have no alternative but to use paraffin and gas so their use does not impart any status, whereas grid electricity would be a status symbol. Later in the urban energy transition, when grid electricity becomes the norm, it, too, will loose its status value. At the top end of the urban energy transition some households seek to enhance their status by using 'enviro-friendly' energy devices, e.g. solar heaters for the pool or a 'traditional/rustic' hearth fire. As with anything else, when everyone has access to a particular energy source, it is no longer a status symbol.

The scope for differentiation and status seeking in the field of appliance ownership is nearly endless. Few households purchase appliances solely for the service they provide. The status of owning the particular appliance or an appliance with particular features or a particular brand name is also a consideration. The status value derived from owning different appliances is affected by many factors: income, cost of the appliance and its 'newness' (does it incorporate the latest technology?), what appliances do other households possess, materialistic orientation, tastes, sophistication, level of modernisation and education, lifestyle, entertainment preferences, etc. It would seem that the household's position in the domestic energy transition process is important in so far as it determines what range of appliances households can meaningfully use to enhance their status.

6.4 Welfare impacts and the domestic energy transition

This section is similar to section 5.3, except instead of investigating the relationship between environmental impacts and the domestic energy transition process, here the focus is on how the *welfare impacts* of household energy use change as they progress through the different phases of the domestic energy transition process. The aim is to identify ways households can increase the level of welfare they derive from their energy use.

As in section 5.3, the standard model is used as a framework for the discussion. Attention is first given to the rural energy transition process, then to changes in welfare impacts that occur during urbanisation, then to the urban energy transition process and, lastly, to some overall trends in the welfare impacts across the entire transition process.

6.4.1 Welfare impacts and the rural energy transition

(i) *First rural transition phase* In this phase most households are able to meet their basic need for energy relatively easily. Some may, however, experience temporary shortfalls due to not being able to fetch and carry fuelwood at all times, say, when it is raining. However, towards the end of the phase the risk of households suffering from energy poverty increases as fuelwood resources start to become scarce.

Fuelwood is used for cooking, heating water and space warming, services which it can perform quite adequately. Candles and paraffin lamps are the principal sources of lighting, but this service is used sparingly due to the high cost of especially candles.

Other welfare enhancing aspects of household energy consumption patterns in the first phase of the rural energy transition include:

- the social function of the hearth fire in many households;
- fuelwood is a 'free' resource in the sense that to obtain it does not require cash; and
- few appliances (apart from pots) are needed. This means there is no "entry fee" or investment required to gain access.

The welfare households can derive from their energy use in this first phase is restricted by the limited versatility of fuelwood - wood stoves are the only appliance in which it can be used. Consequently, households are excluded from a wide range of services such as refrigeration, radio broadcasts, etc. There are also real costs associated with gathering fuelwood. These include the time, effort and risk factors which are invariably borne by women. Other aspects of energy use in this first phase that impact negatively on household welfare include:

- fuelwood and candles are not convenient energy sources to use. They need to be handled, they mess and there are risks associated with their use;
- the quality of the services they supply is not very high, particularly in the case of candles being used for reading or study purposes;
- candles are by far the most inefficient source of lighting;
- fuelwood's specific energy and energy use efficiency is low, which means households have to burn large volumes of it to meet their energy needs. The effort/energy expended in bringing fuelwood to the household is, therefore, quite considerable; and
- there is no credit available to households wanting to invest in energy efficient wood stoves.

Even though fuelwood is readily available in this phase, households should be encouraged to adopt strategies to conserve future supplies. On the supply side households should use only dead wood, plant trees and not destroy tree stocks unnecessarily. On the demand side, wood stoves can improve the efficiency of fuelwood use significantly. However, as noted elsewhere, few households in this phase can afford the capital outlay needed to purchase stoves. Low cost credit for this purpose is needed. Information on other methods of conserving energy, e.g. hot boxes, also needs to be made available. Households should also be encouraged to diversify the energy sources they use so as to be able to get access to energy services that have significant welfare enhancing possibilities, e.g. radio broadcasts.

(ii) *Second rural transition phase* Household levels of energy use are under pressure in this phase due to the scarcity of fuelwood. To maintain energy consumption levels, many households resort to using dung or crop wastes. Despite this, some are still unable to meet their basic energy needs. Energy poverty has serious negative effects on welfare. Households are unable to cook food properly and regularly, they use minimal quantities of hot water and are not able to provide adequate space heating during cold weather. The strategies they adopt to conserve energy can aggravate these negative impacts further. e.g. dung produces more smoke than fuelwood and reducing ventilation to avoid heat loss traps this smoke indoors. The use of paraffin can on the one hand alleviate the energy shortage (and associated negative effects), but on the other hand it may place strain on household budgets, leaving them little income with which to meet other essential needs.

Apart from the negative effects of using dung as a fuel, there is an appreciable decline in the welfare benefits households derive from energy use. Although the range of services is essentially the same as in the previous phase, they are all performed to a lower standard. There is also a significant decline in the reliability of the energy supply. Shortages become a fact of life. The time and effort required to get sufficient fuelwood/ dung is far greater than in the previous phase, i.e. the cost of these energy sources is higher. This is reflected by the fact that in many areas fuelwood is commercialised.

There are few rural areas in South Africa where fuelwood stocks are not under pressure. Therefore a concerted effort needs to be made to improve the reliability of supply of this important energy source through woodlot, afforestation and agroforestry programmes. Overall households' levels of energy consumption and energy service in the second phase of the rural transition are not satisfactory at all. It is important that they establish access to suitable energy sources. In remote areas, this may entail re-establishing fuelwood supplies, e.g. through woodlot programmes. In other instances it may be more realistic to facilitate the transition process. Apart from providing households with greater income earning opportunities, this can be done by:

- providing credit for the purchase of primus stoves, thus overcoming the "access fee" problem;
- extending the electrification programme to rural areas where possible; and
- providing information on the efficient use of energy, e.g. wood stoves, hot boxes and improvements in housing design.

(iii) *Third rural transition phase* Energy use patterns in this phase show that households rely on a range of energy sources including paraffin, gas, coal and electric generators, in addition to fuelwood. The transition to these commercialised energy sources is 'pushed' by the shortage of biomass energy sources noted in the previous phase and 'controlled' by household income levels, the affordability/price of these energy sources and the cost of appliances needed to use these energy sources (the 'access fee'). Another factor determining the rate of energy transition in this phase is the extent and delivery of rural electrification programmes.

In this phase the quantity of energy households consume is expected to be adequate, i.e. more than the minimum specified by the different energy poverty lines, but by no means lavish or excessive. As a result, households derive more welfare from their use of energy in this phase compared to previous phases. In practice this means regular, properly cooked meals, sufficient space warming, greater use of hot water and better quality lighting. The welfare impact is further enhanced by the fact that paraffin, gas and electricity are cleaner, more convenient energy sources than fuelwood or dung. Other positive welfare impacts include greater use of radios (though batteries are expensive), the use of paraffin lamps and a reduction in the fetching and gathering time to obtain energy sources.

Negative welfare impacts of energy use in this phase include the greater use of income to obtain energy. This has both a direct cost and an opportunity cost, since the money spent on fuel cannot be used for other welfare enhancing purposes. The use of paraffin and gas for cooking means the additional space warming and social benefits of the hearth are lost, while the use of coal may in fact aggravate indoor pollution. The transition to paraffin and gas may also lead to increased risks associated with energy use, which detracts from welfare. The dangers of a hearth fire are relatively limited compared to those of an exploding gas canister or primus stove, though the likelihood of the latter occurring may be comparatively low. Despite these negative impacts the overall effect of changes in energy use in the third transition stage are likely to be overwhelmingly positive, particularly given the reduced health risks of the 'new' energy sources.

By the time households reach this stage of the energy transition process, the best means of further enhancing welfare derived from energy use is to facilitate further progress in the transition process, i.e. enabling greater use of paraffin and gas, and facilitating the process of rural electrification. This is best done by increasing household income so that they can afford the energy sources and appliances they require. The process of transition can also be facilitated by enhancing access to credit and providing information on energy conservation, as mentioned above.

6.4.2 Welfare impacts of energy transition during urbanisation

As with the environmental impacts, the effect that the urbanisation process has on the welfare impacts of the energy transition is dependent on which phase in the rural energy transition process households move out of and which phase in the urban transition process they join. As noted previously, most of the rural-urban migration appears to be out of the first and second rural transition phases into the first urban transition phase.

Households making this move obviously make significant changes in their energy use patterns and much of what was said in section 5.3.2 in this regard is relevant here as well. Most households become almost completely reliant on paraffin and coal. A few households from these early rural phases may be fortunate to be able to get access to housing that is electrified on moving to an urban area. They thus join the second or third phases of the urban transition process. Most households moving out of the third rural transition phase are likely to join the third or later urban transition phases. This does not usually involve a great change in their energy use patterns. Not all the welfare impacts of these different changes are discussed here, since they are obvious if the welfare impacts of the rural phases above are compared with the impacts of the urban phases described below. Nevertheless, a number of specific changes are worth noting.

The most important welfare benefit arising from urbanisation is that households are far more likely to gain access to electricity. Given that it is easier and cheaper to electrify urban areas, this is where the electrification programme is focused at present. Should the household indeed get access to electricity, it will in effect be moving into the third phase of the urban energy transition, with all the associated welfare benefits relating to convenience, range of services, cleanliness, safety, etc. These positive welfare effects are, however, tempered by having to purchase appliances (and pay for electricity) and the effect this has on the household budget.

In addition to readier access to electricity, there is also readier access to other commercial energy sources in urban areas. The distribution networks of both paraffin and gas are far more concentrated in urban areas than in rural areas. Through 'spasa' shops paraffin is usually available 'just around the corner', while gas is obtainable from the nearest shopping centre or garage. Appliances to use these fuels are also more readily available in urban areas than in rural areas. Electricity, paraffin, gas, coal and appliances also tend to be cheaper in urban areas than in rural areas. Together these factors are likely to have a positive influence on the welfare of households moving to urban areas.

However, the underlying assumption is that urbanising households will have the income to purchase energy sources and appliances. This is by no means a safe assumption, given the very high levels of unemployment across the country. The likelihood that urbanising households do not have access to adequate income is very high. In urban areas households without access to income find it very difficult to meet their energy needs given that 'free' biomass fuels are very scarce or simply unavailable. Therefore households moving into urban areas may also be moving into energy poverty. Such a deterioration in household energy consumption levels would reduce the welfare they derive from energy use quite considerably. Indeed, it could have debilitating, even fatal, consequences for individual members of households. Possible ways of mitigating the impact of energy poverty in the urban context are discussed in section 7.1.3(a).

Lastly, urbanising households move into new social environments' which has consequences for the way they subjectively regard their patterns of energy use and the status or degree of satisfaction they derive from it. The movement of households to urban areas also lays the foundations for changes in habits and expectations regarding energy sources, appliances and energy use patterns. These changes impact upon the subjective measures of welfare referred to above. For example a primus stove may be a status symbol in rural areas, but in urban areas it is not. The main consequence of these attitude changes is that households adopt more energy intensive lifestyles in urban areas than is the norm in rural areas.

6.4.3 Welfare impacts and the urban energy transition

(i) *First urban transition phase* Two patterns of domestic energy use are found in this phase: in areas where coal is available, households tend to use about equal quantities cf coal and paraffin, while in other urban areas households are almost totally dependent on paraffin. The nature of the welfare impacts is directly linked to which one of these patterns predominate in an area.

The level of energy consumption in this phase is, on average, lower than in all other phases of the energy transition process due to the unavailability of biomass fuels and the need for income to purchase other energy sources. The need to purchase nearly all their energy, as well as appliances, places great strain on household budgets and reduces their capacity to meet their other essential needs. Some households resort to burning cardboard and other unconventional items in order to bolster their energy consumption. This has significant negative welfare impacts.

The use of energy is restricted to meeting basic needs - for cooking, space warming and lighting. In cold weather many households experience severe shortages which detracts from welfare, and can even be fatal due to either hypothermia or carbon monoxide poisoning (especially where households use coal braziers). Where households use coal, impacts of indoor pollution on member's health can reduce welfare significantly.

The welfare enhancing aspects of energy use in this phase are limited, especially where coal is the predominant fuel. Where households use paraffin, the greater convenience, cleanliness and availability of this energy source all enhance household welfare. The only redeeming aspect of using coal is that, if used in a coal stove, it provides good spacing warming.

It is difficult to improve the level of welfare households derive from energy consumption in this phase of the urban energy transition. Electrification may seem an obvious solution, but many households simply cannot afford the initial connection fee, the cost of appliances or the electricity itself. The lack of income is the inhibiting factor. Where households have some income, it may be possible to bridge the 'access fee' problem by finding ways of making credit available to households. Otherwise the only way of enhancing the welfare households derive from their use of energy in this phase is in the area of energy conservation.

(ii) *Second urban transition phase* As noted above, this phase is characterised by rapidly changing patterns of energy use. The most important are the transition to gas and the complementary decline in the dominance of paraffin and coal in household energy budgets. Household consumption of energy also increases across the phase as incomes increase and lifestyles become more energy intensive. Energy poverty in this phase is, therefore, rare, although households may still suffer periodic shortages.

The increased reliance on gas does not increase the range of energy services that households use. Households prefer to wait for access to electricity before purchasing a refrigerator or switching from paraffin lighting, mainly because gas lamps and refrigerators are comparatively expensive. As regards entertainment services such as radio and television, households in this phase often use dry and wet cell batteries to power these appliances. The possession and use of these appliances become a significant status symbol in this phase.

The most important welfare benefit of the transition to gas is that it is a clean, reliable energy source. Its use in the home produces no noticeable indoor pollution. It is also a very efficient fuel. However, the transition to gas is rarely complete. Households continue to use paraffin for lighting and in areas where coal is readily available, households continue burning coal for space warming.

The scope for improving the welfare households derive from their energy use in this phase is again limited. Information on the safe and efficient use of gas can make some impact, but a major improvement is only likely if households' use of coal can be stopped. This is only likely to occur with electrification.

(iii) *Third urban transition phase* This phase sees the advent of electrification. The present emphasis on electrification means many households are getting access to electricity, but the transition to actually using electricity is not as rapid as expected. Households may continue to use gas or paraffin for cooking for some time after being 'hooked-up', but given the convenience and the versatility of electricity there is a tendency to use it to perform all energy related tasks. There is thus an upward trend in households' total energy consumption across the phase.

However, households' consumption of electricity may remain limited for some time after electrification. Households with very low incomes cannot afford any form of commercialised energy source. Electrifying them, therefore, makes very little difference to their overall low level of energy consumption. Indeed, their consumption of energy services may become skewed as a result of electrification, i.e. away from cooking and water heating to greater use of lighting. The nature of electricity is such that it is also difficult for households to monitor their own consumption. As a consequence households may end up consuming more electricity than they can afford, thus skewing their expenditure away from other essential needs. The use of pre-paid metres helps eliminate this problem. The desire to purchase appliances may also result in households incurring more debt than they can afford.

Another welfare reducing aspect of electrification is the fact that the pre-paid meter cards are not as readily available as, say, paraffin. So when a household runs out of money on their card, someone has to make a special trip to the payment centre for a new card. Payment centres are usually only open during office hours and are often not accessible. As a result, households periodically do not have access to electricity, which necessitates maintaining parallel energy systems.

The most immediate welfare benefit of electrification is the tremendous improvement in the quality of lighting. This has important positive externalities for studying and home entertainment. It takes time for households to accumulate other appliances and thus gain access to their services. Lighting is usually followed by television, radio/hifi and refrigeration. Less tangible welfare benefits include cleanliness, the convenience of an on-line energy source and greater security due to improved lighting and sometimes the use of alarm systems.

A comprehensive energy conservation, information and training programme is needed to enhance the welfare households derive from their use of energy in this phase. Areas of particular concern include the conservation of hot water, the purchase of energy efficient appliances and the effective use of electrical heaters. To date Eskom has tended to emphasise only the benefits of using more electricity because the utility's main concern is to increase overall levels of domestic energy consumption in order to make the electrification programme financially viable.

(iv) *Fourth urban transition phase* This phase is characterised by the almost total dominance of electricity in household energy budgets. Other energy sources are only used for specialised functions and for back-up. The main trend in this phase is the increase in energy use that occurs as households accumulate appliances and develop progressively more energy intensive lifestyles. Despite the increases in energy consumption, energy's share of household expenditure tends to decline as overall consumption increases with increasing income.

As in the previous phase, the most important benefit is that electricity is a clean energy source from the domestic perspective. In addition, households gain access to a very wide range of welfare enhancing services as their stock of appliances increases. Indeed access to these services, and to electricity generally, becomes a fact of live and no longer something special.

As noted in section 5.3.3, the most worrying dimension of energy use patterns in this phase is that most households act as if there is a never-ending supply of electricity. They become insulated from and, hence, insensitive to the natural environment. While high income households often show greater concern for some environmental issues, especially those that affect their immediate living environment, they often take little interest or are unaware of the effects their energy use has on broader environmental problems. As noted with the previous phase, a comprehensive energy conservation programme is needed both to educate people about the impact of their energy use on the natural environment and also to create incentives to encourage energy conservation (section 7.2).

6.4.4 Overall trends

The welfare impacts across the entire energy transition vary significantly from the initial rural phase to the last urban phase. This is hardly surprising, given the widely divergent sources of energy, appliances and quantities of energy used in each phase. It is, nevertheless, possible to identify some broader trends in the nature of the welfare impacts of household energy use patterns across the entire energy transition process.

To start with, energy is a 'free' resource in the early rural phases, but becomes increasingly commercialised, until by the second urban transition phase households tend only to use commercial energy sources. There are real costs associated with collecting 'free' energy sources. As energy sources become commercialised, the cost becomes a financial one. In both the early rural and urban phases household incomes tend to be very low. Consequently, expenditure on energy sources represents a significant percentage of total household expenditure. As household incomes increase, spending on energy tends to increase as well, although expenditure on energy as a percentage of total household expenditure tends to fall. By the fourth urban transition phase, households are consuming more energy, but spending less of their income on it, than in any previous phase. This obviously affects households' capacity to meet other essential needs.

Another expenditure related factor is that the level of the 'access fees' and the cost of appliances for each new energy source increases across the energy transition process. It costs virtually nothing to get access to and use fuelwood in the first rural transition phase, whereas to electrify a house in the third urban phase entails a significant capital outlay for hook-up, as well as the purchase of a wide range of appliances in order to use the electricity.

Another positive welfare effect from the household perspective is that levels of domestic energy consumption increase across the entire transition process, despite significant declines in individual phases. The amount of energy that a household consumes at the end of the fourth urban phase is significantly more than at the beginning of the process. Not only that, but the energy sources are far more versatile. So households experience not only an increase in the quantity of individual services they derive from energy, but the range and quality of services also increases. The greatest improvement in this regard occurs when households are electrified. Coupled to this is a movement away from using energy to meet basic needs such as cooking, heating water, space warming and lighting to meeting increasingly non-essential wants, e.g. television, refrigeration, hot blankets, hair dryers, etc.

Lastly, as the domestic energy transition progresses, the scope for households to change their patterns of energy use so as to conserve energy increases, although the need for energy conservation is most keenly felt by households in the second rural transition and first urban transition.

CHAPTER 7

CONCLUSION: CHANGING THE DOMESTIC ENERGY TRANSITION

The analysis of social phenomena such as the domestic energy transition process only has value if the consequent greater understanding can be used to inform the choices that individuals, households, communities and society as a whole are continually making. In section 2.4. it was noted that if sufficient information were available it would be possible to compare each of the different phases of the energy transition process and determine exactly which are desirable shifts in domestic energy consumption patterns and which not. Based on these comparisons it would then be possible to make policy recommendations on how to change household energy use patterns so as to ameliorate the negative environmental and welfare impacts or, alternatively, to enhance the positive ones. This is in effect what this chapter seeks to do based on the analysis and discussion contained in the preceding chapters.

The modus operandi of section 7.1 is to identify problem areas in the domestic energy transition process and then to recommend, very briefly, what should be done to overcome them. The aim is to inform decision making regarding domestic energy use and energy policy generally. The problems cover a range of environmental and welfare issues in line with the integrated approach adopted at the outset of the study (see section 1.3.1). There is thus no strict separation between environmental concerns and welfare concerns. The recommendations themselves are aimed at various levels of decision making - national, provincial, local and individual - and it is usually obvious which level is relevant in a particular instance. Recommendations relating to individual behaviour are made on the basis that in many instances, if things are to change, individuals have to take action, and also on the realisation that micro changes combine to form macro changes. The maxim 'think globally, act locally' referred to in section 1.3.3 is also relevant here. This is particularly true of section 7.2, where recommendations on ways of conserving energy within households are considered.

Given that this is the concluding chapter of this study, section 7.3 makes recommendations as to possible areas for further study and section 7.4 provides a visual summary of the main points of chapters 2 through to 6.

7.1 Impacts and recommendations

The key areas of concern in the domestic energy transition process tend to stand out either on the basis of the number of people involved or the extent of the impact on the environment. The discussion of the different problems is very brief, relying mostly on references to preceding sections of the study. The aim is simply to provide some background to the recommendations that follow.

The standard model (see section 2.3.3) is used as a framework for the discussion. Attention is first given to problems in the rural energy transition process, then to ones relating to the urbanisation process, followed by those in the urban energy transition and, lastly, to some issues of an overarching nature.

7.1.1 Problems in the rural energy transition

When considering ways of alleviating the negative impacts of the rural domestic energy transition there are two points to remember. Firstly, electrification offers no solution to the energy problems already being experienced in rural areas. As is noted in sections 5.1.1 and 5.1.7.1(b), rural electrification will take time - probably not less than twenty years and then many areas will still not be connected simply because it is too expensive (Stavrou, 1992:5). Even if electricity were to be made readily accessible in rural areas, the vast majority of rural households do not earn sufficient income to support a monthly electricity bill, let alone the cost of hook-up and the purchase of appliances. Other ways of addressing rural households' energy problems are therefore called for. Secondly, the scope for resolving the energy problems being experienced by rural households is severely constrained by their limited access to income earning opportunities and, hence, to cash incomes. Any recommendations have to take this into account and where some capital outlay is required provision needs to be made for micro loans. Even then the uptake, on a voluntary basis, is likely to be very low unless the benefits are significant.

(a) *Energy poverty in rural areas*

Households in the second phase of the rural energy transition are particularly at risk to energy poverty (section 2.3.3.2). Geographically speaking these households are most often located in arid and semi-arid areas of the country, as well as the eastern escarpment (section 6.1.1). The factors giving rise to energy poverty in rural areas include the scarcity of fuelwood (caused by an increasing population placing pressure on the natural resource base) and the lack of income to purchase commercialised fuels (section 3.3.1). The effects of energy poverty on household welfare are discussed in section 6.1.1. They include undercooked meal, severe indoor pollution, the use of unsterilised water, a lack of space warming and the use of low grade fuels such as dung and crop wastes. Households with low average levels of energy consumption are also at greater risk of suffering a shortage of energy at a time when it is essential for survival.

Another important welfare impact associated with energy poverty in rural areas is the high real cost of collecting fuelwood. As noted in section 6.2.1(b), this task is invariably performed by women and involves considerable time, effort and risk.

There are no quick-fix solutions to energy poverty in rural areas, principally because household incomes are very limited. There is thus no scope for 'spending out of the problem', which is why many stoves, solar cookers and other energy saving devices designed for rural areas have made little impact. If households had the income they would use paraffin or gas. The primary solution, if there is such a thing, is to seek ways for rural households suffering from energy poverty to earn cash incomes sufficient to purchase commercial fuels. Failing this, ways need to be found to re-establish access to fuelwood and to increase the efficiency with which the households use energy. It is in this light that the recommendations below are made.

Recommendations:

- *The government should implement, as a matter of urgency, projects to re-establish households' access to fuelwood in those areas where households are reliant on dung/crop wastes for energy (see section following).*
- *Existing wood stove and hotbox projects need to be extended. Government support is needed to ensure that rural communities that are unlikely to receive electricity in the near future are serviced by these projects so as to ensure they use fuelwood resources available to them efficiently. The possibility of subsidising these appliances to the extent that they become affordable should be considered.*
- *Information on appropriate housing designs, materials and construction methods needs to be disseminated so as to ensure that all new rural dwellings are as energy efficient as practically possible. Special attention should be given to capturing the so called 'lost opportunity' features, namely building orientation and appropriate material use. Attention should also be drawn to the energy conserving features of traditional dwellings so that these can continue to be incorporated in new dwellings.*
- *Information on how to conserve energy and use fuelwood most effectively should be compiled and disseminated in rural areas.*
- *There should be an ongoing campaign aimed at redefining the collection of fuelwood, as well as water, as men's work, so as to alleviate women of the burden.*

(b) *Loss of tree cover*

In many rural areas the demand for fuelwood is too great to be met sustainably from the existing resource base. As a result there has been a severe loss of tree cover across the whole of South Africa, which has serious environmental implications (section 5.1.1(v)) as well as the welfare consequences due to its impact on household energy consumption patterns (see sections 6.1.1, 6.2.1(b) and 6.4.1(ii)). To counteract these negative impacts, measures need to be taken to ameliorate the use of fuelwood (demand side) and re-establish tree stocks (supply side).

Demand side measures fall into three broad categories. Firstly there are those aimed at increasing the efficiency of fuelwood use. Numerous models of wood stoves have been designed with these aims in mind. Karekezi (1990:1-23) reports on various surveys that indicate that stoves can bring about fuelwood savings of between 19% and 60% - depending on their design. At present the dissemination of stoves in the rural areas of South Africa is very limited. There is thus scope for fuel savings by this method. However, the spread of stove technology is being hindered by the emphasis on electrification. As mentioned above, electrification is not the solution to the energy problems in many rural areas. This needs to be impressed upon people so that alternate energy strategies are planned and implemented. Secondly, the consumption of fuelwood can be reduced by conserving energy generally. Ways of doing so are discussed in greater detail in section 7.2 below. Methods appropriate to rural and peri-urban areas include locating and orientating the dwelling place so as to utilise the area's micro-climate effectively, designing the house to conserve energy and constructing it with appropriate insulating materials, using hot boxes for cooking, only keeping the fire alight when necessary and heating water whilst cooking. Thirdly, it is possible to reduce fuelwood consumption by getting households to use other energy sources. Fuelwood may be replaced by paraffin, coal, gas or electricity, if it is available. This would be in line with the domestic energy transition process. Otherwise biogas and sun cookers may be viable options.

Addressing the loss of tree cover/deforestation problem from the demand side has its advantages. If the demand for fuelwood can be reduced, the rate at which existing tree stocks are being destroyed will fall and a stage may even be reached where the stocks are able to regenerate naturally. More importantly, the benefits of the demand side measures accrue directly to the individual households that adopt them. Many of the changes can also be implemented at minimal cost and achieve results rapidly. Lastly and probably most importantly, the expertise and organisational infrastructure required to co-ordinate demand side changes are minimal compared to an afforestation or agroforestry programme.

Supply side measures represent the other side of the coin. The problem is that the stock of trees is too small to meet both the present and future demand for fuelwood. Therefore measures need to be taken to increase the stock. The first set of measures is directed at utilising existing tree stocks more efficiently. This includes both those that are far away from the point of demand and those to which access is restricted by legal titles of ownership and conservation considerations. Some areas, such as on commercial farms or plantations, have a latent supply of fuelwood. The immediate problem is that to transport fuelwood is costly, because of its low energy density. Transport costs can be reduced by converting wood into charcoal, which has a higher energy density than wood. However, the production of charcoal is very wasteful of wood resources, so unless it is utilising a source such as plantation residues or encroachment bush, its impact may defeat the object of conserving trees (Eberhard, 1986:17;

Rivett-Carnac, 1982:11). In the second instance, restricting access to certain wood stocks may be counter productive. It makes sense for owners of private land to harvest and sell the wood on their land in a sustainable manner. In conservation areas people may be given the right, a servitude as it were, to collect dead wood. This would not only meet their need to some extent, but also give them an interest or stake in the existence of the reserve. In a small way this would be linking people's development needs to conservation.

The second set of measures aims to increase biomass fuel supplies. This is usually equated simply with planting more trees. Much has been written about the need for afforestation and woodlots. (See for instance Eberhard (1986), Gandar (1983) and Aron *et al.* (1989).) However, experience in other countries suggests that this type of energy planning has seldom been successful because the planning model used has been 'top down' and even where local people have been involved, "it is typically the economically and politically dominant men who control proceedings whilst those who need the wood most, women and the landless, are largely excluded" (Soussan, 1988:99). Soussan (1988:100) notes that the basic problem with most woodlot and afforestation projects is that they do not meet the people's needs:

> Land is developed for one use only, to grow trees. Often this runs counter to people's needs; for example, communal grazing land is alienated from the people, or tree species which grow slowly, but are valued for a range of uses, are replaced by fast-growing but single-use trees which people do not know and do not wish to know. In other words, they fail because those in charge do not recognise the complexity and diversity of the way rural people interact with their local environment to provide for a range of needs.

Tree planting projects that have served to strengthen the role of trees as a component of subsistence farming systems have often been more successful. The aim of so called 'agroforestry' projects is either to introduce new crop-tree combinations or to extend this type of farming to areas where it is not traditional. As far as the production of fuelwood is concerned, this approach has a number of advantages. Firstly, fuelwood is already being supplied from trees on farmland. Therefore agroforestry strengthens existing patterns of production and is readily recognised by farmers as meeting their needs. Secondly, present fuel gathering techniques concentrate on wood that is small in diameter. This offers the possibility of developing short rotation 'energy trees' which could easily be integrated into existing production systems. Thirdly, agroforestry can provide a continuous supply of wood, which can be 'harvested' much like any other crop by techniques such as coppicing and pollarding. Fourthly, the trees do not have to be exclusively fuelwood trees but can provide fruits, poles for construction, environmental protection and other outputs. Finally, agroforestry can increase the land's total productivity (Soussan, 1988:103).

Recommendations:

Most of the recommendations made above with regard to alleviating energy poverty in rural areas are also relevant here, as is much of the discussion of energy conservation in section 7.2. Recommendations specifically relevant here include:

- *The fact that electrification is not the solution to rural energy problems and to the problem of loss of tree cover needs to be acknowledged by government and action taken to address the problems directly, through stove projects (see above), energy conservation education (section 7.2.1) and tree planting programmes (see immediately below).*
- *Communities living in close proximity to conservation and forestry areas should be granted servitudes to collect dead wood for their own energy needs.*
- *The feasibility of afforestation, woodlot and agroforestry projects should be investigated thoroughly. This should lead to the implementation of a "national tree planting project" which seeks to meet communities' needs for tree products (fuelwood, timber, fruits and natural remedies) while upgrading the environment. It may be most efficient to extend the capacity of NGO's working on projects of this nature already. Special care must be taken to involve communities in the development and implementation of such projects and to ensure that the projects are directed to meeting community needs.*

(c) *Indoor pollution*

During the rural energy transition, indoor pollution is a problem in all households that use biomass fuels or coal without a stove or without a hearth with a functioning chimney. Regular exposure to such smoke may have serious consequences for people's health (section 5.1.1). Households suffering from energy poverty are particularly at risk since dung and crop residues smoke profusely and because in their efforts to conserve warmth they often reduce ventilation (section 5.1.2). The use of coal braziers is also a significant cause of indoor pollution (section 5.1.4). Although paraffin burns a lot more cleanly than all the above fuels, it also raises levels of indoor pollution to the extent that it may be unhealthy (section 5.1.3).

The problem of indoor pollution can be addressed in a number of ways. Firstly, it can be reduced by using the energy sources and the energy produced during combustion more efficiently. Numerous models of stoves have been designed with these aims in mind and, as is noted above, the savings can be significant. Secondly, conserving energy generally and thus reducing the amount of smoke producing fuel that is burnt in the dwelling will reduce indoor pollution. Thirdly, it can be limited by using cleaner energy sources, which may include charcoal, paraffin, gas or electricity, as well as alternate energy sources such as solar energy and biogas.

However, the most effective solution to indoor pollution is a stove with a chimney. Karekezi (1990:7, 9 and 11) reports that the majority of wood stove users in both India and Guatemala cite smoke removal as the most important reason for adopting various types of stoves. Failing the use of a stove, a hearth with a proper chimney can also be effective.

Recommendations:

- *The Department of Health should publicise the dangers of indoor pollution as an integral part of its basic health programme.*
- *The government should (as suggested above) also support the dissemination of wood stoves by making micro loans available to households wanting to purchase them, as well as by subsidising them to reduce the price for households, as argued earlier.*
- *Schools, the media and clinics should provide people with information on the amenity and health benefits of effective hearth chimneys. Information on different construction techniques should be made available as well.*
- *Information on the dangers and proper use of braziers should be disseminated.*

7.1.2 Problems of energy transition during urbanisation

Many households moving from rural areas to urban areas move into a position of energy poverty. This is especially so where households move out of the first or third rural energy transition phases and into the first urban transition phase (compare the descriptions of these respective phases in sections 2.3.3.3 and 6.4). Levels of energy consumption tend to be very low in the first urban transition phase because incomes are so low that households cannot afford to purchase the energy they require and, unlike in rural areas, 'free' biomass fuels are unavailable (section 6.1.1). This move into energy poverty can be particularly stressful for a household that moves from a warmer to a colder climate, e.g. from KwaZulu-Natal's coastal area to Gauteng. There is no immediate solution to this problem, except to emphasise the importance of employment and access to adequate income.

Another problem associated with the process of urbanisation is that it leads to the concentration of the negative environmental impacts arising from households' use of energy. In rural areas the impacts of domestic energy use tend to be fairly dispersed. Consequently, the environment is able to absorb the smoke produced by households with little or no adverse effects. When households move to urban areas the impacts are concentrated into a smaller environmental 'pool' and as a result are more likely to be critical (section 1.3.2). The intermediate level air pollution in many residential areas resulting from the domestic use of coal is a good example (section 5.1.4), as is the almost non-existence of tree cover around some urban areas.

More wealthy households insulate themselves from these impacts by using electricity and by creating an attractive urban environment through planting of trees. Trees can be planted in any residential area, something the new local councils should tackle. As regards reducing intermediate level air pollution resulting from the urban use of coal, the discussion below is relevant.

7.1.3 Problems in the urban energy transition

The greatest negative impacts of energy use in urban areas are associated either with energy poverty in the first phase of the urban energy transition process or with the domestic use of coal. These impact directly on the welfare of households. Less obvious are the environmental impacts that result from the energy intensive lifestyles of many middle and high income households.

The exceptionally rapid rate of urban electrification is a key consideration when considering problems in the urban energy transition. Often households are being expected to move directly form the first and second phases into the fourth phase. There is nothing inherently wrong with this, but in many instances there is no 'structural compatibility' (section 2.2) between existing patterns of energy use, their levels of income, their stock of appliances and this new source of energy. As a result households are often unable to take full advantage of the opportunities it offers. This is largely due to the lack of access to appliances.

(a) *Energy poverty in urban areas*

Households in the first phase of the urban energy transition can often only afford to buy very limited amounts of paraffin or gas. As a result they are particularly at risk to energy poverty (section 2.3.3.2). The lack of income is the principal cause, but the unavailability of alternatives to commercial fuels is a factor as well. Whereas poor households in rural areas have access to 'free' biomass energy sources, poor urban households rarely do, although they sometimes supplement their energy budgets by burning cardboard, plastics and other non-conventional fuels to provide warmth. The effects of energy poverty in urban areas is much the same as in rural areas discussed above. To recap, they include undercooked meal, severe indoor pollution, the use of unsterilised water, a lack of space warming and the use of low grade fuels. In addition households in a state of energy poverty are more likely to suffer a critical shortage of energy when it is essential for survival (section 6.1.1).

As with energy poverty in rural areas, there are no quick-fix solutions. Indeed, the options may be even more limited, as there is little scope for 're-establishing' supplies of fuelwood within urban areas. As before, the primary solution is to create income earning opportunities for the poorest households and thus provide them with sufficient means to purchase commercial fuels.

Recommendations:

- *The allocation of demarcated plots needs to be facilitated so that households can be given access to electricity as soon as possible. When households have access to electricity, the government should consider subsidising a 'life-line' quota to alleviate the worst ravages of energy poverty.*
- *As noted in section 7.1.1(a), information on appropriate housing designs, materials and construction methods needs to be disseminated so as to ensure that all new dwellings are as energy efficient as practically possible. Special attention should be given to capturing the so called 'lost opportunity' features, namely building orientation and appropriate material use. Attention should also be drawn to the energy conserving features of traditional dwellings so that these can continue to be incorporated in new dwellings.*
- *Information on how to conserve energy and use energy most effectively should be compiled and disseminated.*
- *The possibility of building community size biogas plants should be considered seriously, since they would help alleviate energy shortages and provide a hygienic method of treating sewerage.*

(b) *Urban use of coal*

The use of coal for domestic purposes is concentrated in and around the coalfields of Gauteng, Mpumalanga and KwaZulu-Natal. The most important impact of the urban use of coal centres around air pollution both at the intermediate/neighbourhood level and at the micro/household level. These impacts are discussed at some length in section 5.1.4. A very brief summary is given here. The most serious impact is that the quantity of wastes emitted by domestic coal fires usually exceeds the local environment's capacity to absorb and disperse them effectively. As a result air pollution levels in some residential areas such as Soweto often exceed official guideline levels. Such levels of air pollution seriously affect people's health (increasing the risk of cancer and aggravating chest conditions), reduce the amenity of living in the area, corrode buildings and other structures and damage plants and trees. If coal is burnt indoors with no ventilation, carbon monoxide poisoning can result in death.

Households can limit their emissions by burning cleaner grades of coal (if they can afford them). More important is for coal emissions inside the dwelling to be kept to a minimum. A coal stove is the most effective method of doing so. An open coal fire should not be lighted in a dwelling where there is no proper fireplace and chimney.

Neighbourhood pollution can only be ameliorated if less coal is consumed. Firstly, both the energy source and the energy produced during combustion must be used more efficiently.

According to Lennon and Turner (1991:8), coal stoves use about 50% less energy to cook a basic meal and for space heating than an open coal fire. Consequently, coal stoves generate about 50% less emissions in performing these tasks. Most coal stoves also heat water while in use, thus using energy more efficiently. Secondly, conserving energy generally can reduce the need to consume coal (section 7.2). Thirdly, coal consumption can be reduced by switching to cleaner energy sources. Electricity is widely regarded as the best alternative, yet the extent to which this reduces pollution levels in areas such as Soweto is not clear. Clarke (1991:150) argues that the shift from coal to electricity is unlikely to be complete, since many households prefer coal stoves. Up to 22% of households in Soweto with electricity still use them (Heyl, 1988). It is therefore suggested that a smokeless stove fuel should be made available instead of forcing people to use electric stoves. This route was followed in the United Kingdom after the London smogs of the 1960's. "Only when the option of buying smokeless fuel was open to all were smokeless zones declared" (Clarke, 1991:150). Smokeless coal or charcoal is likely to be more costly than coal, which is also the main reason why better grades of coal (anthracite), paraffin and gas are not used more widely and intensively.

Recommendations:

- *Information on the dangers of indoor pollution caused by coal fires/braziers should be disseminated along with information on measures households should adopt to alleviate the problem. Here the dangers of sleeping next to a brazier or coal fire should be emphasised.*
- *Areas that suffer from severe smoke pollution should be prioritised for electrification.*
- *Eskom should consider swapping electric heaters for coal stoves in order to encourage households to use electricity for space warming instead of coal.*
- *The possibility of declaring residential areas smoke free zones once they have been electrified for some time should be investigated.*

(c) *Access to appliances*

The services that households derive from appliances make an important contribution to household welfare and the realisation of a 'modern lifestyle'. As noted in section 6.2.4(a), these services can be divided into four broad categories: the services of 'key' appliances, i.e. those that enable the household to actually use energy sources; services unique to a particular appliance, e.g. television; services that enhance the quality of a particular energy service, even though the use of the appliance is non-essential; and services that 'make life easier'. The possession of appliances is very unevenly spread among households, largely due to the inequalities of income and wealth that exist in South Africa.

In section 6.2.1(c) it was noted that the cost of appliances was an important determinant of whether a household can in fact adopt a new energy source in line with the energy transition process. The cost of appliances acts as an 'entry fee' which households must pay in order to progress. It was also noted that each household had an 'affordability threshold' which limited its capacity to pay the entry fee and thus progress in the energy transition process. The existence of this entry fee is well recognised with regard to electrification and appropriate loans and tariff structures have been introduced as a result. However, there is not the same appreciation for the affordability threshold/entry fee gap at earlier stages in the energy transition. Consequently, credit is not available to households needing to purchase appliances that could enable them to progress in the energy transition process or contribute significantly to their welfare.

As is noted in section 6.2.3(b), the normal functioning of credit markets favour more wealthy households, even though poor households have a greater need for credit, given that their incomes are so low that even a modest initial investment in a new energy system or appliance is unaffordable. At present poor households have to pay more for credit (in the informal market) than rich households, which does nothing to alleviate the maldistribution of benefits and opportunities between rich and poor. Clearly there is a need for a credit scheme that enables poor households, particularly in rural areas, to overcome the 'entry fee' barriers that face them at different points in the energy transition process.

Recommendations:

There is a strong correlation between a household's level of income and its level of appliance ownership. The most effective means of increasing levels of appliance ownership is, therefore, to make sure households have access to income earning opportunities and that the incomes they earn are sufficient to enable them to invest in appliances, i.e. more than a mere subsistence income. Job creation strategies are beyond the scope of this study. The following recommendations focus on specific strategies to promote low income households' access to appliances.

- *The government should promote the creation of special credit facilities for the purchase of energy efficient wood and coal stoves in areas that are not likely to be electrified in the near future and for the purchase of even the most modestly priced appliances, such as primus stoves, so that very poor households can hurdle the affordability threshold and obtain the appliances needed to take advantage of new energy sources.*
- *Information on the construction of home-made energy efficient wood stoves that also have chimneys should be made available. This could be done through clinics as part of the basic health programme. This may even entail holding demonstration workshops so as to familiarise prospective users with the technology.*
- *Newly electrified households should be offered a package deal on a set of energy efficient appliances, the cost of which can be recovered as an additional amount added*

to the electricity bill. Eskom does operate such a scheme in some areas, but its focus is to raise household electricity consumption levels so as to make the connections economically viable. Eskom therefore offers households appliances that are heavy energy consumers, i.e. electric stoves, kettles, heaters and irons, rather than allowing households to determine what services they need and want. This scheme has potential, but needs to be aimed at meeting customers needs rather than the utilities needs. One of the ways of doing this is to give newly electrified households a once-off, fixed credit allowance which they can use to purchase any electrical appliances either from the utility or from participating stores. As with the present scheme, the repayments would still be linked to households' electricity purchases. Such a scheme would help overcome the lack of credit available to poor households for the purchase of electric appliances.

(d) *Energy intensive lifestyles*

Electricity lends itself to consumption: it is convenient, clean, versatile, nearly always available and cannot be physically handled and measured like other fuels. As a result households with access to it tend to develop energy intensive lifestyles, acting as if there is a never ending supply (sections 5.1.7.1 and 5.3.3(iv)). Electricity insulates households from the environmental impacts of their energy use and as a result they tend not to take an interest in maintaining its quality by conserving energy. The integrated nature of household and environmental welfare cannot be ignored even if electricity provides a clean environment from the household perspective.

Recommendations:

- *A progressive electricity tariff structure that penalises high levels of consumption should be implemented to encourage affluent households to conserve energy, while still giving poor households access to the benefits of electricity.*
- *A Pigouvian tax or carbon tax should be incorporated into the electricity bills of all homes electrified before, say, 1985 to generate funds for pollution control.*
- *Information on how the use of electricity affects the environment needs to be made available to people, so as to educate them about the links that exist between the environment and household welfare.*

7.1.4 Overall considerations

(a) *Electrification*

Electrification has not been the focus of this study. Nevertheless, the importance of this process for the overall domestic energy transition process is undeniable. The rapid rate of electrification is moving hundreds of thousands of households each year from the early phases of the urban energy transition into the fourth phase. The implications for the environment and for household welfare are discussed at various points throughout the study. Here the emphasis is on highlighting some issues (and recommendations) that follow from these discussions.

(i) *Pre-paid meters*

Nearly all new electricity connections utilise pre-paid meters. The aim of using these meters is to overcome the problems associated with the non-payment of electricity accounts. However, as noted in section 6.4.3(iii), the 'electricity cards' needed to operate these meters are not readily available, since payment centres are usually only open during office hours and are often not accessible to consumers.

Recommendations:

- *Eskom and the municipalities should locate payment centres with the convenience of the consumers in mind.*
- *Eskom should investigate the possibility of developing card dispensers, like ATMs, that give consumers access to electricity cards on a 24 hour basis.*

(ii) *Cross-subsidisation*

In section 6.2.3 it is noted that connecting a household to the national grid costs upwards of R2300, which does not include the cost of appliances. These capital costs or entry fees represent a substantial barrier to poor households. Eskom and some municipalities have recognised this and so have introduced schemes whereby the supplier bears the installation cost initially, with only a nominal fee being levied for the hook-up. The shortfall is then recovered via a surcharge on the household's electricity consumption. However, this scheme is running into difficulties because newly connected households are not consuming sufficient energy to generate the revenue needed by Eskom to cover the interest on the capital outlay of its electrification programme. Therefore to avoid a spiralling debt burden, Eskom has started a system of cross-subsidisation whereby all consumers on the grid contribute towards the cost of grid extensions. This cross-subsidy was not part of the original electrification programme. It has been introduced in an effort to keep the programme viable.

This *ex post ad hoc* approach to cross subsidisation is unacceptable. When white communities and farmsteads were being electrified, the capital costs were borne by all consumers on the grid (section 6.2.3). Cross-subsidisation was an integral part of the electrification process, not an add on. The suggestion is therefore that the cost of all new connections in the present electrification programme also be borne by all consumers on the grid. This would be a relatively simple matter if Eskom was solely responsible for electricity distribution. However, the fact that municipalities and private companies, in addition to Eskom, do distribution makes it difficult to determine how a cross-subsidy should be administered other than on an *ad hoc* basis. This is an important issue since it determines whose capital outlays are being subsidised. The recommendations below do not address this last question since a more detailed analysis is needed before suggestions can be made.

Recommendations:

- *The notion that the electrification programme can or should pay for itself, except in the very long term, must be abandoned.*
- *At present, the revenue flowing from new consumers does not cover the interest payments on the capital outlay Eskom made to link them to the electricity grid. Consequently, unless alternative funds are generated the increasing debt burden may jeopardise the continuation of the programme. Therefore the electrification programme should be re-costed to take into consideration the lower than expected consumption (revenue) from newly connected households. Then an appropriate rate of cross subsidisation from existing consumers must be calculated in order to pay for the programme and tariffs adjusted accordingly.*

(iii) *Impacts of power lines*

The discussion in section 5.1.7.2 indicated a number of areas where power lines have a seemingly unnecessary impact on the environment. Eskom's policy is to consider up to a 15% increase in the cost of building power lines in order to lessen environmental disturbance. Possible measures include the rerouting of lines to avoid sensitive areas, the use of helicopters to eliminate access roads and the use of pylons that occupy less space (Eskom, 1992:33 and 35). Gandar (1985:64) points out that such "an arbitrary upper limit" does not allow for the varying conservation needs of different areas.

Recommendations:

- *Eskom should adopt a policy of "taking all reasonable measures" to lessen the environmental impacts of power lines, rather than using a 15% cost increase as the limiting factor.*

(iv) *Generating electricity*

This study focuses on the vario[illegible] the domestic energy transition process. The attention given to the environ[illegible] arising from the generation of electricity must be seen in that context, as [illegible] the recommendations that follow. The discussions in section 5.1.7.3 noted that domestic demand for electricity accounts for 15% of all the electricity sent out in South Africa. Consequently roughly one seventh of the environmental impacts of generating electricity may be attributed directly to households. It is therefore incumbent on households to take an interest in the consequences of electricity generation and possible ways of ameliorating those impacts.

This is over and above any general level of concern people should have for the maintenance of a healthy environment.

In the debate about limiting emissions emitted during the generation of electricity, three issues are especially pertinent to the discussion of the domestic energy transition process. The first relates to the idea that a trade-off exists between pollution control/ desulphurisation and electrification. It has been expressed by Eskom (1992:32) as follows:

> For a power station with an installed rating of 3 600 megawatt, the cost of desulphurisation would be of the order of R2 billion, before running costs. The effect would be to reduce rainfall acidity by 2.3% and ambient sulphur dioxide levels by 6.9% ... . By contrast, R1 billion invested in the electrification programme would bring electricity to 420 000 homes. This would improve air quality in the townships by 70%.

Firstly, suggesting, as this does, that a trade-off exists between desulphurisation and electrification may sound compelling, but the argument is wrong. Electrification and desulphurisation are just two projects in Eskom's large portfolio of capital projects. Instead of comparing only these two with each other, Eskom should arrange all the projects in increasing order of nett social benefit. The funds available for investment would then determine where the cut-off point should be. It may be that projects such as the electrification of farms or research on possible nuclear sites should be scaled down to release funds for both the above projects (Engelbrecht, 1991:7). It should also be recognised that consumers bear a responsibility toward both projects. As noted above, when white communities and farms were being electrified, it was government policy that the capital investment costs should be borne by all consumers on the grid (Stavrou, 1992:5). When the present electrification drive was undertaken, the intention was that there would be no such cross-subsidisation. Apart from being unjust from the point of view of the new consumers, this would have limited the rate of electrification. However, this approach has proved not to be feasible given the political imperative of supplying electricity to as many homes as possible as rapidly as possible. Consequently, about 2.5% of all existing consumers' electricity payments goes towards subsidising the process (Opperman, 1994:3). A similar approach should be used to provide funds to clean up the environmental effects caused by the generation of electricity. Such a charge would amount to a Pigouvian or carbon tax on the use of electricity. Equity considerations suggest that those consumers that have enjoyed the services of electricity for a longer period of time should pay proportionally more to clean up. It would be impossible to implement such a system by targeting individual consumers, but it could work if the extra levy were to be linked to all houses electrified, say, before 1985.

The second issue revolves around the question: Who should bear the cost of pollution? At present most of the costs of pollution are borne by society as a whole and by future generations. This means that polluters, who are the consumers of electricity, are being 'subsidised' to pollute and the people paying this subsidy - i.e. suffering the cost of pollution - are being forced to do so. This is both unethical and unjust. According to the 'polluter-pays-principle', the consumer price of electricity should reflect the full cost of producing it. In other words the external cost of pollution from generating electricity should be internalised - so that the consumer pays it. This may be achieved in two ways: (i) by adding a Pigouvian or carbon tax equivalent to the marginal social cost of generating electricity to the present consumer price of electricity, or (ii) by passing the cost of pollution control measures on to the consumer via the price of electricity. Option (i) makes the consumer pay the full cost of pollution, but does not specify how this revenue should be allocated, whereas option (ii) reduces the difficulties of determining marginal social costs and links price changes to specific pollution control measures. Both methods are likely to entail a substantial upward correction in the price of electricity: Eskom (1992:32) claims the cost of desulphurisation would add 30%, but Clarke (1991:149) argues that the figure is "inflated to discourage the public from demanding pollution controls". This raises the third issue, namely, the need for an agency which determines environmental policy and standards and that has sufficient independence and clout to ensure their effective implementation. The present division of responsibilities between government departments are not conducive to effective environmental protection.

Recommendations:

The aim here is not to specify all that needs to be done to ameliorate the environmental impacts of the coal generation of electricity. This requires a separate study. Instead, a number of recommendations that follow from the analysis in section 5.1.7.3.1 are made.

Spreading the impacts

- *All new coal-fired stations, without any exception, must be located outside the Mpumalanga Highveld and away from densely populated areas.*
- *Given that the 'high stacks' policy is only partly successful, more attention needs to be given to controlling air borne emissions at source.*

Spreading only ameliorates micro and intermediate impacts, but not the macro impacts, particularly those caused by gaseous emissions.

Controlling the emissions that cause the macro impacts

- *Households should be encouraged to conserve electricity and to use it during off-peak periods. This would modify overall demand patterns and hence reduce the production of emissions. Measures aimed at achieving this are discussed in section 7.2.*
- *Eskom must continue investigating ways of modifying the electricity generating process so as to use coal more efficiently and to reduce the formation of toxic gasses. In this regard new technology, such as coal gasification and fluidised bed combustion, could make a significant difference. Improvements in the thermal efficiency of existing stations are important as well.*
- *Gaseous emissions should be controlled at the end of the generating process using add-on cleaning equipment. Particulates are already controlled in this manner, and desulphurisation equipment has been mentioned. There are also various other technologies for cleaning flue gasses which should be assessed.*
- *Society as a whole, but with Eskom taking the lead, should undertake to plant sufficient trees to 'mop-up' the carbon dioxide produced during the coal generation of electricity. It is estimated that at least two billion trees would be needed; a modest 100 million trees per year would accomplish the task in twenty years. Such a project could have a dual purpose: cleaning the atmosphere and revitalising rural areas. The latter would take place since most trees would have to be planted in rural areas, thus ensuring an adequate energy supply and restoring the environment. Agroforestry may be the best approach to such a project. It is important to note that such a tree planting project would not conflict with the Department of Water Affairs project to remove alien vegetation to conserve water. The alien vegetation is being removed from areas that originally did not support dense stands of trees, whereas the tree planting project would aim to restore the tree cover in areas where it has been depleted and where it is part of the natural eco-balance. Planting trees in areas that receive heavy rainfall would also conserve water by reducing the speed of run-off thus allowing water to seep into the ground to replenish the water table.*

Measures aimed at controlling emissions of liquid effluents and solid wastes are generally effective. Nevertheless, the institutional framework for protecting the environment needs to be strengthened.

Controlling the impacts of coal mining

- *An independent agency to monitor and enforce environmental quality standards needs to be set up to replace the present fragmented system.*
- *There needs to be a review procedure to ensure that companies (i) set aside sufficient funds during the lifetime of a mine to rehabilitate it once it is mined out and (ii) to ensure*

that they actually carry out the rehabilitation when mining ceases. Many larger companies have self-imposed controls in this regard, but the scope for abuse still exists.

Reducing the consumption of coal

- *Attention should be given to investigating and developing alternative, cleaner energy sources for generating electricity. An obvious possibility is the use of the natural gas off the Southern Cape in combined-cycle turbines. Such technology is relatively simple and it may therefore be a more cost-effective way of utilising these gas reserves than Mossgas. Other options include using the tremendous hydro potential of the Congo River, micro hydro systems, solar energy and wind energy.*
- *The possibility of imposing a carbon tax on the mining of coal so as to encourage the development of renewable energy systems (section 5.1.7.3(e)).*

Nuclear energy

The ensuing suggestions are premised on the belief that the risks and social costs that nuclear power imposes on present and future generations and the power structures that control it cannot be defended on ethical grounds.

- *People need to be informed of the environmental, ethical and technical problems, as well as the social costs, of nuclear power and the disposal of nuclear waste.*
- *Control of the nuclear industry should rest with Parliament (not the government) or with an autonomous publically accountable organisation. In either case the Constitutional Court should have final control.*
- *South Africa should follow Sweden's lead and aim to phase out nuclear power by 2010, i.e. no new nuclear facilities should be planned, let alone built.*
- *Research funding should be redirected from nuclear research to the research and development of alternative energy sources.*

Hydro-electricity

- *Efforts to develop the subcontinent's hydro-potential should be encouraged and backed-up with the necessary research.*
- *More research funding and capital finance should be made available for the development of small hydro-electric projects. These could either be linked to the national grid, or be used to electrify dwellings in remote rural areas. Both China and Indonesia have used such schemes to good effect (Ward, 1988:196; Doppegieter et al., 1992:3-46).*

Alternative technology

- *The development and dissemination of technology using renewable energy sources for generating electricity needs to be speeded up.*
- *More research and development funding should be channelled towards renewable energy projects.*

- *The price of electricity should be made to reflect or at least approximate the marginal social cost of generating it - this would make renewable energy sources more competitive.*
- *Energy policy and Eskom's mission should be re-orientated towards long term sustainability rather than supplying present customers with electricity at "the cheapest possible price" (Eskom, 1992:10; Gerholm, 1992:22-23).*
- *Information on the real costs of different methods of generating electricity needs to be made widely available so that people can lobby both government and Eskom regarding the continued use of environmentally damaging energy sources and the neglect of renewable ones.*

(b) Importance of lighting

Lighting, though not a basic need, can make an important contribution to households' quality of life (section 6.2.4(b)). Lighting enables households to extend activity times after dark, which means that household members, particularly scholars and students, may to spend more time reading and studying, which would have a direct impact on literacy and overall educational standards. Electric lighting is the preferred source of lighting because of its convenience, quality and low risk. Households use other sources of lighting purely out of necessity. Given the importance of lighting for education and, hence, future income earning opportunities, improving the quality of lighting households have access to can significantly improve their welfare levels both now and in the future.

Recommendations:

- *Households presently using candles as their main source of lighting should be encouraged to use paraffin lamps since they are a better quality, cheaper source of light. As with other appliances, ways of enabling poor households to purchase these lamps need to be investigated.*
- *Information on the safe and effective use of candles, paraffin and gas lamps should be made available, particularly through clinics and schools. The aim would be to enhance the benefit derived from these lighting sources, given that many households are unlikely to get access to electric lighting in the near future.*
- *The manufacturers and distributors of wet-cell batteries should investigate the market for lighting from this energy source, especially in rural areas and in squatter areas where either the remote location or the lack of proper land tenure excludes the possibility of electrification. This may lead to the development of a credit scheme to encourage households to purchase batteries. It may also be possible to set up small entrepreneurs to service, recharge and recycle the batteries that households use to power lights and audio-visual equipment, as well as those used in cars. Apart from the cost of the*

batteries themselves, the cost of recharges is a major obstacle to the use of this source of energy for lighting.

- *Eskom should investigate the possibility and implications of downgrading non-paying consumers' access to electricity so that they can only use it for lighting. This approach still provides households with an incentive to resume payment, but does not jeopardise scholars' educational opportunities, especially since they rarely have any say as to whether a household maintains payments or not. The cost of maintaining such 'light links' is a social investment that the government may consider subsidising.*
- *Eskom and the municipalities should design schemes, e.g. replacement purchases, to encourage all electrified households to use fluorescent lights both because this source of lighting is cheaper and because it is energy efficient.*

(c) *Using gas*

As is noted in section 5.1.5, gas is the cleanest energy source that is commercially viable at present. Its use is even less polluting than electricity produced from coal. Gas is also more efficient than all other fuels and it is for this reason that people concerned about the environment suggest that it be used as a 'bridge' from the existing fossil fuel based energy system to more sustainable energy technologies. It provides a low pollution alternative to oil and coal while the new solar, wind, hydrogen and superconductivity technologies are developed and disseminated. As noted above, it may make economic sense to seek alternative ways of using the gas off the southern coast, given the failure of Mossgas (section 5.1.7.3(d)).

Recommendations:

- *The government should encourage the domestic use of gas - even among those households with electricity - in view of its cleanliness and efficiency. People should also be educated in the safe use of gas, so as to limit leakages and accidental explosions.*
- *The possibility of extending the piped gas networks in Cape Town, Sasolburg and Johannesburg, as well as starting new networks, should be investigated. It may be feasible to supply towns in the Southern Cape with natural gas from Mossgas, as well as pipe it to Cape Town and Port Elizabeth/Uitenhage. Using the natural gas directly is more efficient, probably cheaper and less environmentally damaging than using it to produce liquid fuels as is presently the case.*

7.2 Energy conservation

The discussion in section 5.2 highlighted numerous ways in which energy conservation can ameliorate the negative impacts of energy use on the environment. Discussions in other sections have indicated that energy conservation can also enhance household welfare by reducing expenditure on energy and by improving the home environment. The discussion of energy conservation is included in this concluding chapter because it is the one dimension of domestic energy consumption that truly integrates the environment with household welfare, in addition to being relevant to all phases of the domestic energy transition. As is noted in section 5.2, the aim of energy conservation is to increase the efficiency with which present energy services are delivered, as well as to curtail certain uses of energy.

Section 7.2.1 looks briefly at the issue of responsibility for energy conservation and the need for a national conservation campaign; section 7.2.2 looks at ways of improving the energy efficiency of South Africa's housing stock; section 7.2.3 deals with ways of conserving electricity; and, lastly, section 7.2.4 addresses the issue of using alternative energy sources.

7.2.1 Promoting energy conservation

Efforts to conserve energy in the domestic sector in South Africa are woefully inadequate. Awareness of the potential and need for energy conservation is low among households, while bodies that may have been expected to take the lead have by and large failed to do so. The near universal lack of interest in energy conservation amongst municipalities probably stems from the fact that they generate substantial profits from retailing electricity (Gervais, 1987:6; Theron, 1992:11). Eskom is in much the same position; saddled with massive over-capacity, the utility wishes to sell as much electricity as possible. This is certainly one of the motivating factors behind the electrification drive, as well as the promotion of appliances that use large amounts of power (stoves, heaters, irons and elements for heating water) among newly connected households (Van Gass, Eskom: personal communication). Eskom's energy-use efficiency programme is aimed at increasing its share of the industrial energy market, rather than reducing energy consumption. Its efforts in the latter direction are confined to providing information, which falls far short of conservation programmes being implemented by utilities in other countries (Eskom, 1992:33; Nadel 1992:515-520). The government has also not provided a clear lead. Various departments have conducted energy awareness campaigns, but a long term energy conservation programme seems to be something of a bureaucratic orphan: many departments have a limited interest, but none of them want the full responsibility.

As far as promoting the conservation of fuelwood and coal is concerned, various non-government organisations have undertaken projects, but are finding it difficult to disseminate the technology they have developed due to a lack of manpower and the weak financial position of rural and peri-urban households.

From an environmental perspective, people have a social and moral responsibility to conserve energy. Each household should take the necessary action and by the same token government, Eskom, municipalities and other suppliers of energy should be fostering the process far more actively than at present.

Recommendations:

- *An independent commission financed by government should be formed to oversee energy conservation policy (Gervais, 1987:6). Apart from initiating programmes itself, such a body could also use legislation to force [illegible] municipalities to undertake or promote certain conservation measures.*
- *Such a commission should be made responsible for researching and promoting the conservation of all forms of domestic energy use. The following policy instruments might be considered: information and educational programmes, cash rebates and low interest loans for the implementation of conservation measures and the purchase of energy efficient appliances and legislated building standards.*
- *Eskom should be required to investigate the feasibility of conserving electricity with load management schemes, energy audits, progressive tariff structures and off-peak discounts.*
- *Legislation prescribing appliance performance standards and compulsory appliance performance labelling should be passed (Nadel, 1992:515-520; Gervais, 1987:2).*

The manner in which each of these programmes are implemented is obviously crucial to their success.

7.2.2 Improving the energy efficiency of housing

In areas with extreme climates, the potential for saving energy by improving the thermal efficiency of houses is significant. Although South Africa's climate is for the most part temperate, there is still potential for reducing the amount of energy used to moderate indoor temperatures. Many of the measures involve using the passive heating effects of the sun or reducing the impact of such effects. Table 7.1 summarises the measures that can be adopted to improve the energy efficiency of existing houses.

Table 7.1: Measures to improve the energy efficiency of houses

Measures that cost nothing	Measures that cost a little	Measures that are relatively expensive
- keep inside doors closed so that only rooms in use are heated or cooled - use doors/windows for ventilation and to control indoor temperatures - seal chimney and open hearth when not in use	- plant deciduous trees that shade windows and east and west walls in summer - use blinds/curtains to block unwanted sunlight - seal doors and windows - circulate cold/warm air with a fan - use thermostat switch on air conditioners	- install ceiling insulation - use reflective glass - add outside window shutters - place a heat outlet over stove - change outside walls and roof to appropriate colour (dark in cold areas and light in warm areas)

Sources: 1. RSA, 1978:42-43
2. Nasionale Bounavorsingsinstituut, 1977:18-19

Many conservation features can be incorporated when designing a house that to retrofit later would be more expensive or sometimes impossible. These so called 'lost opportunity measures' include correct orientation, the use of aspect and local climatic conditions, the use of roof overhangs suited to the latitude, the installation of appropriate window sizes, and building with materials suited to the area (Nadel, 1992:526; Nasionale Bounavorsingsinstituut, 1977:19). Since the turnover of housing stock is very slow, it is important to capture the savings from these lost opportunity measures in each new house. It has been noted that indigenous hut architecture in some areas already use measures such as orientation, aspect, ornamentation and building material to optimise indoor temperatures (Siegfried, 1984:1-2). The use of these measures needs to become universal.

Recommendations:

- *Building codes that incorporate conservation standards should be promulgated. These would aim to capture most of the 'lost opportunity measures'.*
- *Explicit attention should be given to factors such as orientation and aspect when planning low cost housing schemes.*

7.2.3 Conserving electricity

The scope for energy conservation in electrified households is large because, though it sounds contradictory, awareness of the need to conserve electricity is low. A concerted education campaign is needed to inform people of common-sense ways of conserving electricity. Table 7.2 lists many of the measures that such a campaign would aim to bring to the attention of households.

Table 7.2: Measures households can adopt to conserve electricity

Service or appliance	Measures that cost nothing	Measures that cost a little	Measures that are fairly expensive
geysers	- set thermostats at 55°C	- insulate hot water pipes	- match geyser size to that of household - locate geyser close to point of use
hot water	- use cold tap	- fit economical shower heads	
stoves	- match size of pot to stove plate - switch plate/oven off before cooking/baking is complete - defrost foodstuffs before heating - keep lids on pots while cooking	- use pots with flat conductive bottoms - use pressure cookers - seal oven door	use microwaves
refrigerator/ freezer	- defrost regularly - allow hot foodstuffs to cool before refrigerating	- seal doors	- match size of refrigerator/freezer to size of household
lights	- switch off when not in use	- use task specific lighting	- replace incandescent bulbs with fluorescent bulbs
heaters	- close doors of room being heated	- set a thermostat	- buy infrared heaters
other appliances	- switch off when not in use		- buy efficient appliances

Sources 1. RSA, 1978:42-43
2. Nasionale Bounavorsingsinstituut, 1977:18-20

Whether the campaign is conducted by the government, Eskom, municipalities or an independent commission set up for the purpose, it will need to be backed-up by other measures in order to encourage people to take action.

Recommendations:

- *The tariff structure of electricity should be used to provide households with a price incentive to save electricity. Both a declining block tariff and a flat rate tariff fail to give appropriate price signals. Instead, a progressive tariff should be used which caters for the basic electricity needs of the poor and penalises households that consume excessive amounts. At present such a tariff structure would be contrary to Eskom's policy of using low prices as an incentive to increase electricity sales. It also means that there may be a measure of cross-subsidisation, since it costs more per unit to deliver a small amount of power than large amounts (Eskom, 1992:15). The government may, therefore, have to intervene to persuade/force Eskom to change its tariff policy.*

- *An education programme should be run in conjunction with a programme whereby Eskom and/or municipalities conduct free energy audits for households, so as to advise them of the conservation measures they should adopt and what the cost may be. Various incentives such as rebate programmes or low interest loans could then be used to encourage households to take action (Nadel, 1992:519).*
- *Distributors of electricity should all implement load management schemes that switch-off hot water geysers during peak demand periods.*
- *Measures to improve the average efficiency of the domestic appliance stock and of appliances marketed in South Africa need to be implemented. To start with, the government should legislate minimum appliance performance standards that become progressively stricter over time. This will raise the average efficiency of appliances available to consumers. There should also be compulsory appliance performance labelling, so as to encourage customers to take efficiency into account when purchasing an appliance.*
- *Households should be encouraged to purchase the most efficient appliances available. This may be done by Eskom providing cash rebates or low interest loans to customers purchasing efficient appliances. From the point of view of Eskom, investing in an efficient appliance stock may be more cost effective than increasing electricity output or building new power stations.*

All the above measures will tend to increase the effectiveness of any educational campaign promoting energy conservation (Nadel, 1992:518-520).

7.2.4 Using alternative energy sources

The contribution that alternative energy sources can make to conserving energy varies with the type of technology, as well as with the acceptability and cost thereof. It also depends on whether the alternative energy is used to replace conventional energy sources or to supply an additional/new energy service.

In the discussion on improving the thermal efficiency of houses, various measures to hinder or enhance the passive heating effects of solar energy were noted. Households can use solar energy to conserve other types of energy in a number of other ways as well. Solar water heaters used to feed warm/hot water into a geyser could reduce the amount of electricity an average household uses to heat water by about 3700 kilowatt-hours per year or by over 30% (Rivett-Carnac, 1990:36-37). This is a significant saving in electricity, but to realise it the price of solar water heaters would have to fall substantially. At 1989 prices solar heaters offered households no savings in total costs and, therefore, no incentive to make the capital outlay (Rivett-Carnac, 1990:38). Eskom should consider subsidising the capital cost of installing solar heaters as a cheaper option to having to invest in new generating capacity. Where households do not have access to electricity, solar heaters would still help to conserve energy, but the main benefit would be an increase in the availability of hot water. Again, cost constraints would need to be overcome to realise these benefits (Eberhard, 1986:12).

Stand alone photovoltaic systems can supply households not connected to the national grid with sufficient electricity for lighting, television and radio. The main benefit of using such systems is that they save grid electricity, which is mostly generated from non-renewable resources. Other savings are small: candles, paraffin and gas, as well as dry and wet cell batteries used to power televisions and radios. Photovoltaics may be competitive in remote rural areas far from the national grid, or in areas where wet cells are used extensively. Otherwise costs would need to fall considerably before widespread use would be viable (Eberhard, 1986:11; Rivett-Carnac, 1990:42; Doppegieter *et al.*, 1992:3-43).

Solar cookers are also often advocated as a way to conserve energy. Various designs exist and they all can cook most types of food in a reasonable period over midday - without using any fuel. Although this saving is substantial, other features of the technology have been found to make it inappropriate to people's needs. So despite concerted efforts to disseminate cookers, few households use them (Eberhard, 1986:20; *Die Burger - bylae*, 30 April 1993:1).

Biogas has been mentioned as an enviro-friendly alternative to burning dung, fuelwood and paraffin, as well as an energy source for the generation of electricity. In each case it would be conserving the energy resource it replaces. Other environmental benefits of biogas are that it burns cleanly and efficiently, it is a renewable resource and it is produced without destroying organic material. The improvements in health derived from processing sewerage in biodigestors is an important secondary benefit. Rivett-Carnac (1982:114-121) investigated the feasibility of biogas technology in South Africa and found that family scale plants could be viable in rural areas if obstacles such as unreliable water supplies, a lack of technical ability and costs could be overcome. A medium scale plant operating on a commercial sized diary, pig or poultry farm was found to be viable and under certain conditions could even give a good return on investment. Economies of scale made larger plants even more attractive. Biogas, therefore, appears to be an energy source worth investigating and developing. The only negative environmental impacts of biogas is that methane contributes to global warming if released into the atmosphere and, as with all gases, there is the risk of accidental explosion.

Hotboxes, although not an alternative energy source, can reduce the amount of energy used for cooking by allowing food to cook in the residual heat after being heated to boiling point. Hotboxes can be used in conjunction with any energy source, but a survey in KwaZulu-Natal found that paraffin was most commonly used. The same survey indicated that the regular use of a hotbox could enable a household to conserve between 1.1 and 5.7 litres of paraffin per week, with the lower figure being more likely. A saving of 1.1 litre amounts to about a 10% reduction in weekly paraffin consumption (Gandar and Udit, 1988:5). A positive aspect of this technology is that fuel-saving is not the only benefit users cite; others include convenience, time saving, better quality food and ability to cook food while at work. Hotboxes were also noted to have facilitated the transition from fuelwood to paraffin and even gas (Gandar and Udit, 1988:4 and 6). They are, therefore, a very desirable form of technology from an environmental perspective. Their low cost also makes rapid dissemination a possibility. It may be an idea to sell hotboxes in conjunction with primus stoves.

Recommendations:

- *Funding for nuclear research should be redirected to research into alternative energy sources.*
- *Some of the funds being made available for electrification should be used to subsidise solar water heaters, wonder boxes and the construction of community size biogas plants so as to help alleviate energy shortages in areas that are unlikely to be electrified in the near future.*

7.3 Areas requiring further study

The scope of this study is very broad; as a result, many issues have not been dealt with as thoroughly as would have been possible if they had been the single focus of a study. In addition new data on domestic energy use have been collected since the main body of this study had been completed, which would have been useful to incorporate, but time constraints have made it impossible. It is for these reasons that the following list of topics for further study is suggested:

- The South African Living Standards and Development Survey (SALDRU Survey) collected a lot of data on domestic energy use. It would be interesting to see how this information impacts on the analysis and conclusions of this study.
- Research is needed to establish verifiable energy poverty lines for South African conditions.
- Research is needed to establish what households' energy needs for cooking are, taking people's diets and nutritional needs into consideration.
- A study needs to be made of different rural electrification scenarios in order to establish which areas are not likely to receive electricity within, say, the next five years so that alternative strategies for meeting the energy needs of these areas can be developed.
- Research into the extent and consequences of loss of tree cover is needed in order to direct reforestation programmes.
- Practical policies for implementing agroforestry through public works programmes need to be studied.

- Each new housing project needs to be assessed in order to identify ways of capturing the so called 'lost opportunity measures' - this should be an ongoing research/policy project.
- A study of the energy efficiency of the South African housing stock would be useful in identifying ways of conserving energy.
- Research needs to be done to determine whether using the gas off the southern coast for generating electricity is not more cost effective than Mossgas.
- Research should be done to determine the commercial viability of establishing community sized biogas plants for processing sewerage and generating electricity.
- Research into the possibility of producing wet cell batteries suitable for providing affordable lighting in rural areas is needed.

7.4 A visual summary

This section gives a somewhat cryptic summary of the main points of the study. The six figures that follow show the standard model of the domestic energy transition process as described in section 2.3.3 and figure 2.5 along with text boxes below each of the transition phases. The information in these text boxes differs in each figure according to which aspect of the study is being summarised.

Figure 7.1 summarises the main characteristics of each of the different phases of the domestic energy transition as described in section 2.3.3.3.

Figure 7.2 summarises the causal factors which tend to move the energy transition process forward in each of its phases. This figure is based on the discussion in section 3.3.

Figures 7.3 and 7.4 summarise the positive and negative environmental impacts of energy use in each of the phases of the domestic energy transition process. These figures are based on the information in chapter 5, especially section 5.3.

Figures 7.5 and 7.6 summarise the positive and negative welfare impacts that distinguish each of the phases of the domestic energy transition process. These figures draw on the information in chapter 6, especially section 6.4.

Finally, figure 7.7 summarises some of the various measures that might be taken to ameliorate the negative environmental and welfare impacts of domestic energy consumption in each of the phases of the domestic energy transition process, as well as measures that can move the process forward. In this case the information is drawn primarily from the foregoing sections of this chapter.

Figure 7.1: Main characteristics of each phase of the domestic energy transition

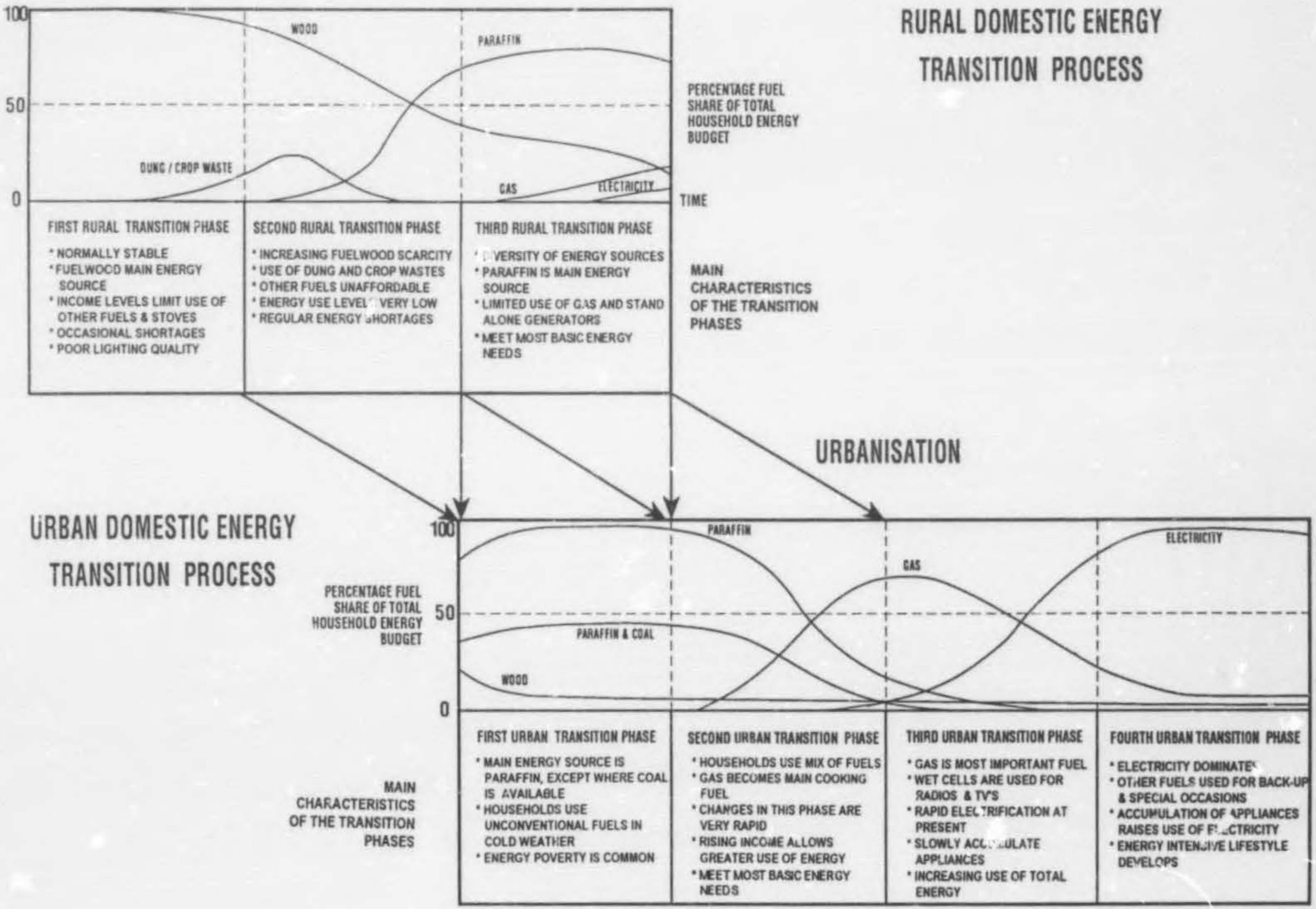


Figure 7.2: Causal factors that determine domestic energy transition

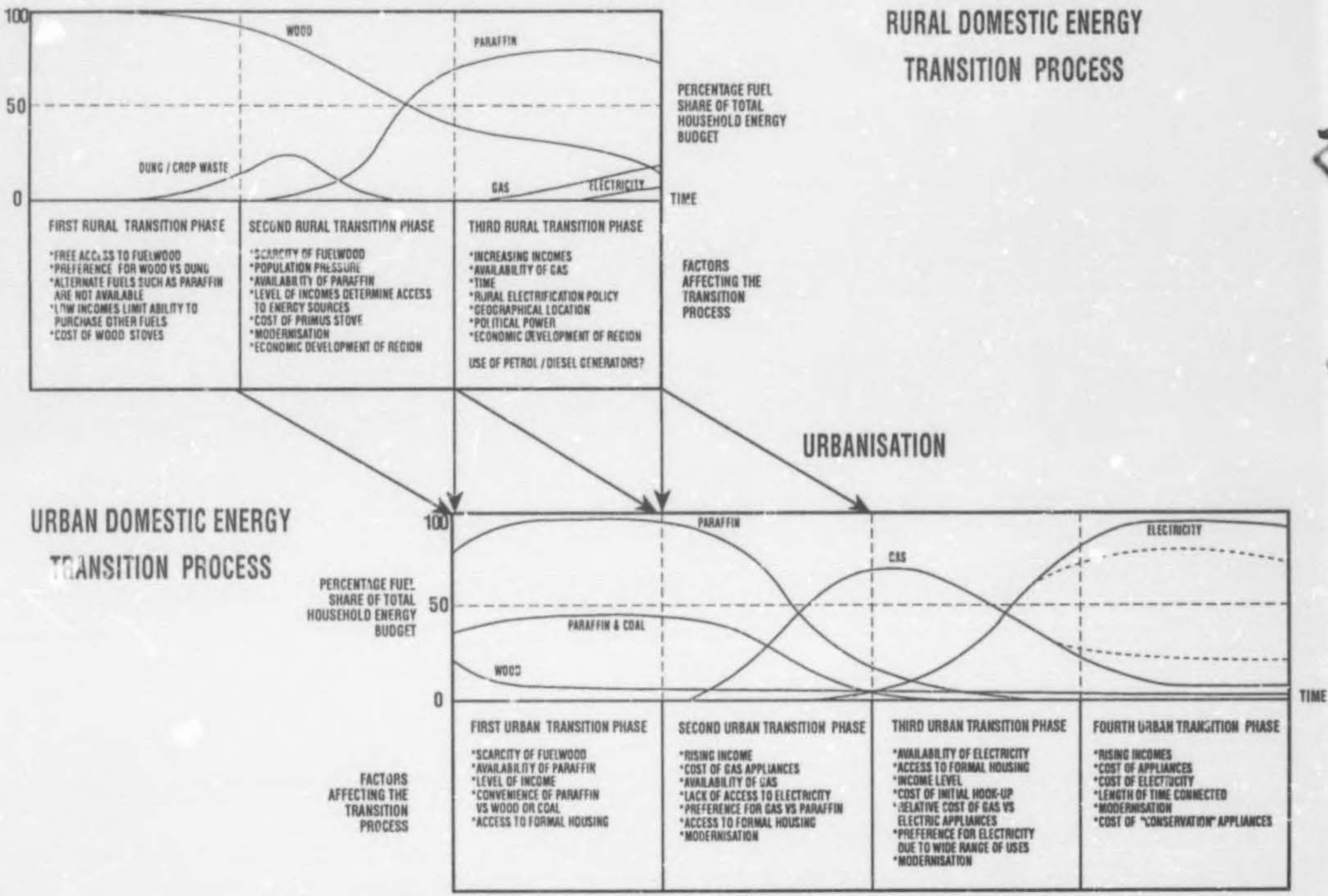


Figure 7.3: Negative environmental impacts of energy use in each phase of the domestic energy transition process

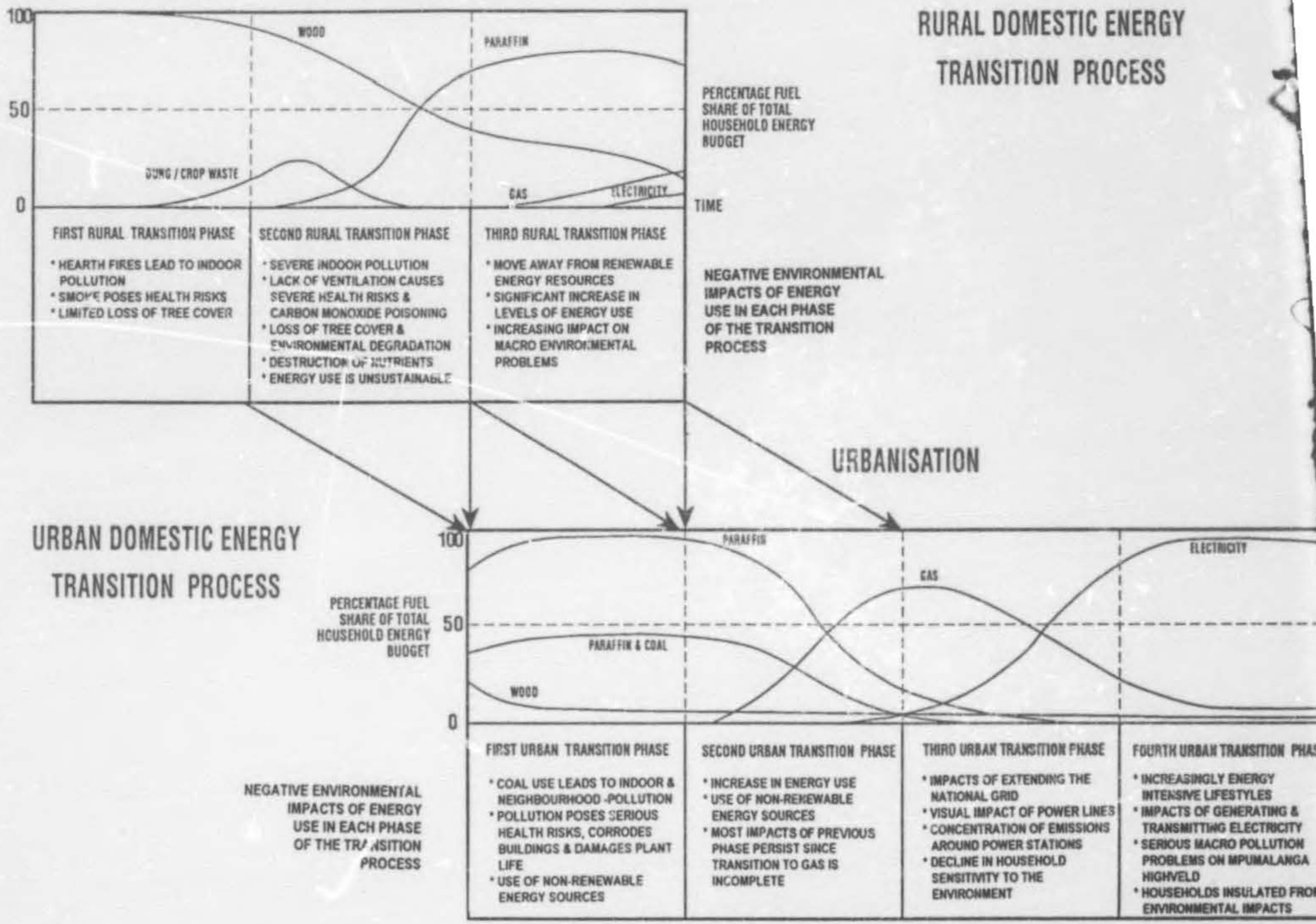


Figure 7.4: Positive environmental impacts of energy use in each phase of the domestic energy transition process

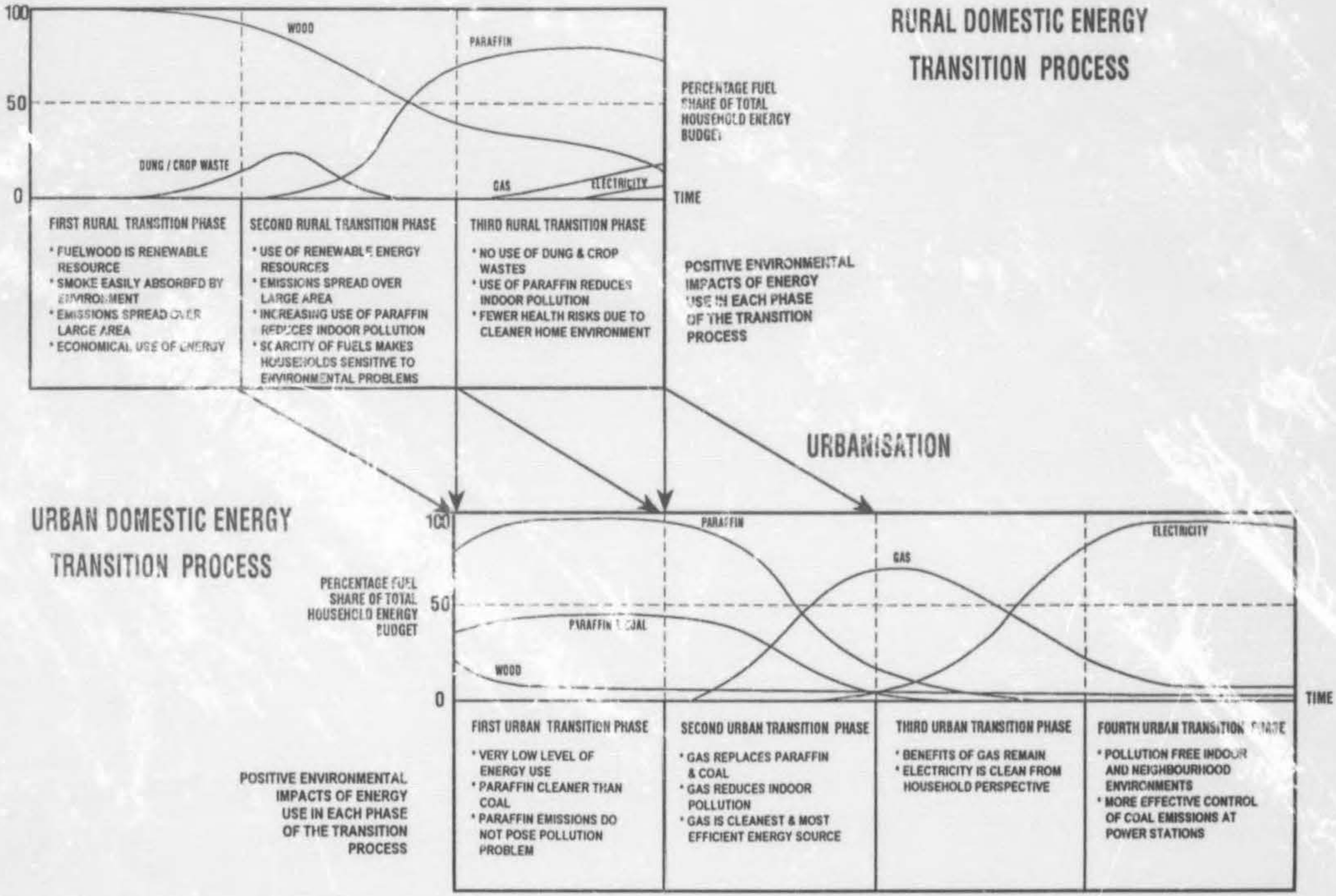


Figure 7.5: Negative welfare impacts of energy use in each phase of the domestic energy transition process

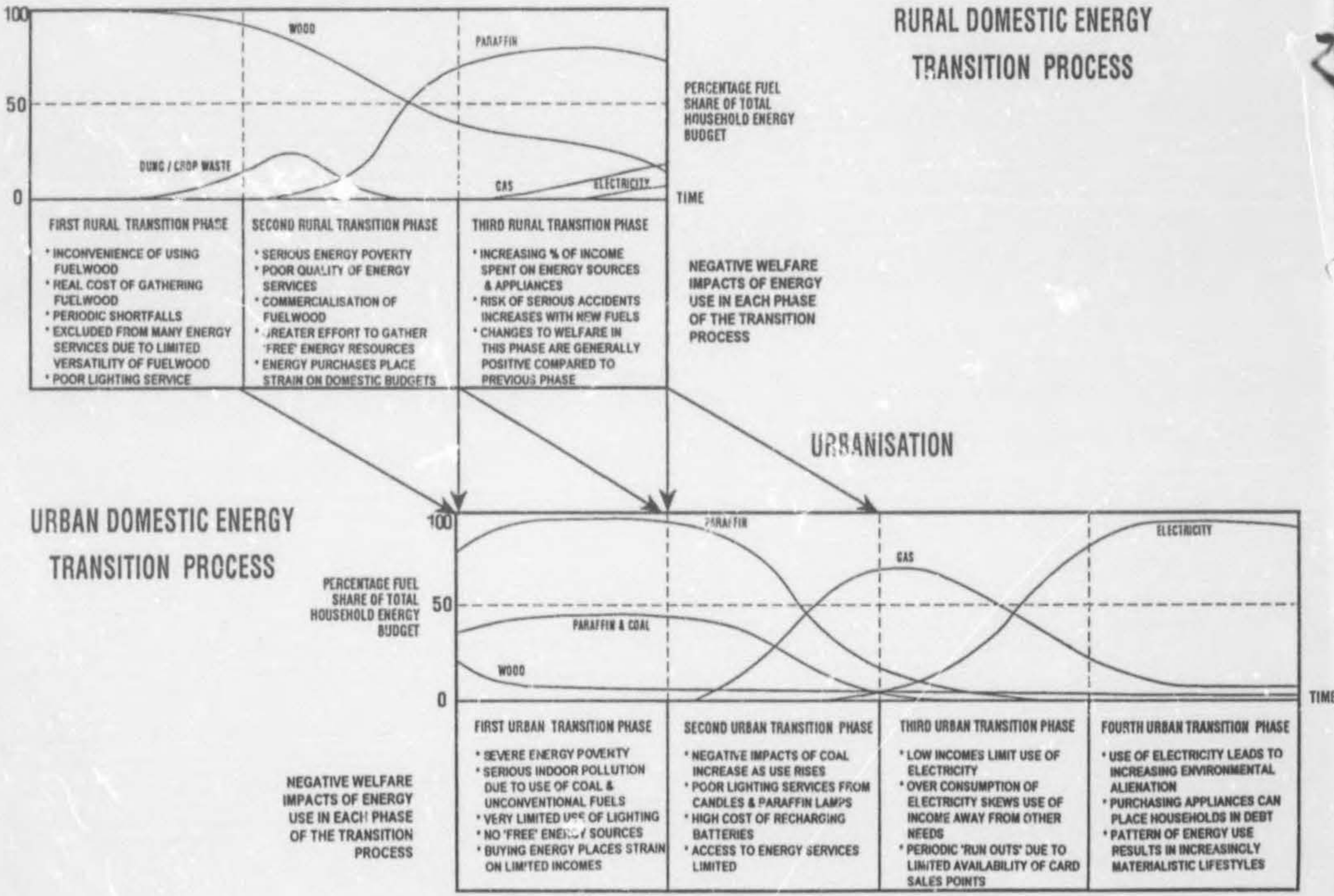


Figure 7.6: Positive welfare impacts of energy use in each phase of the domestic energy transition process

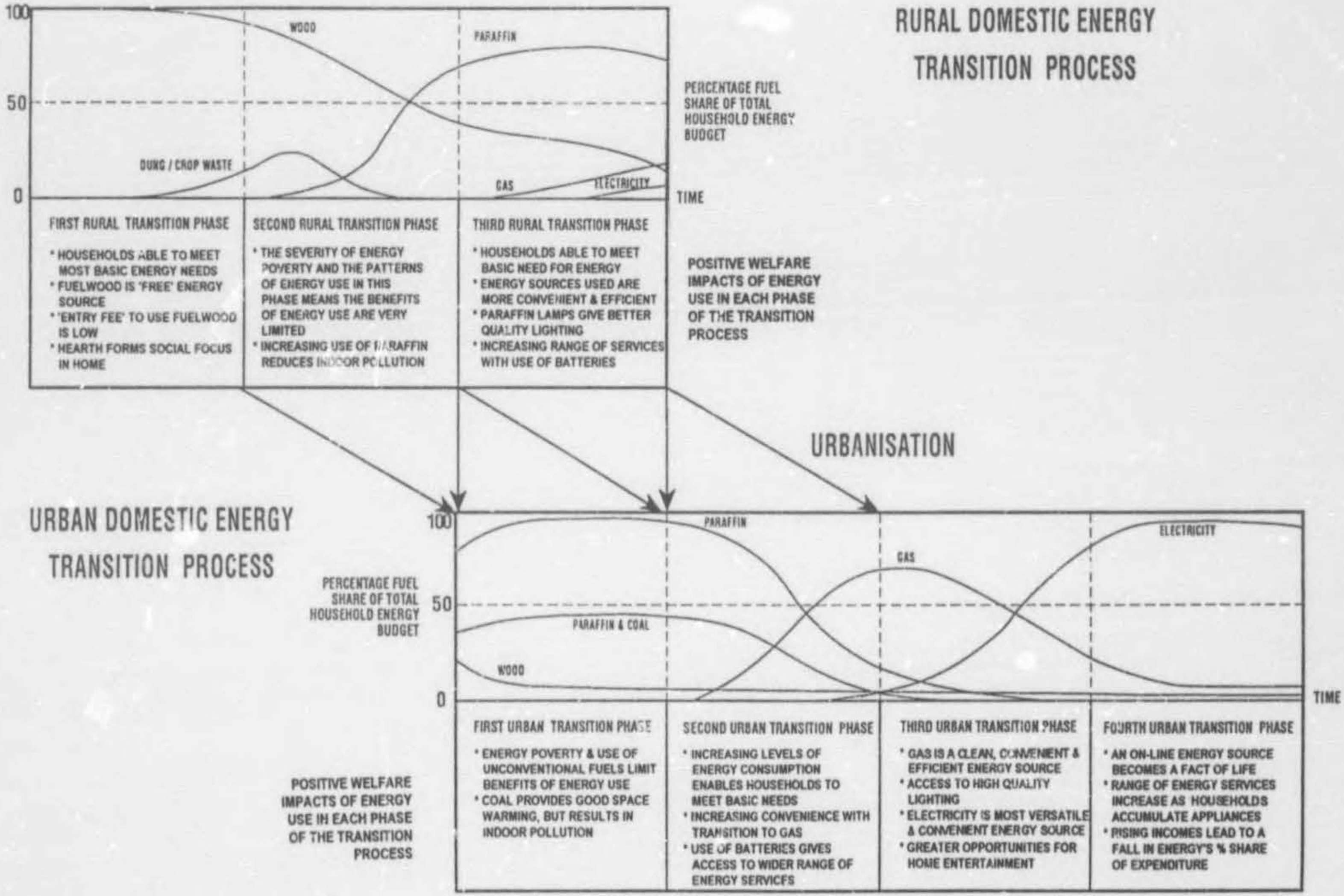
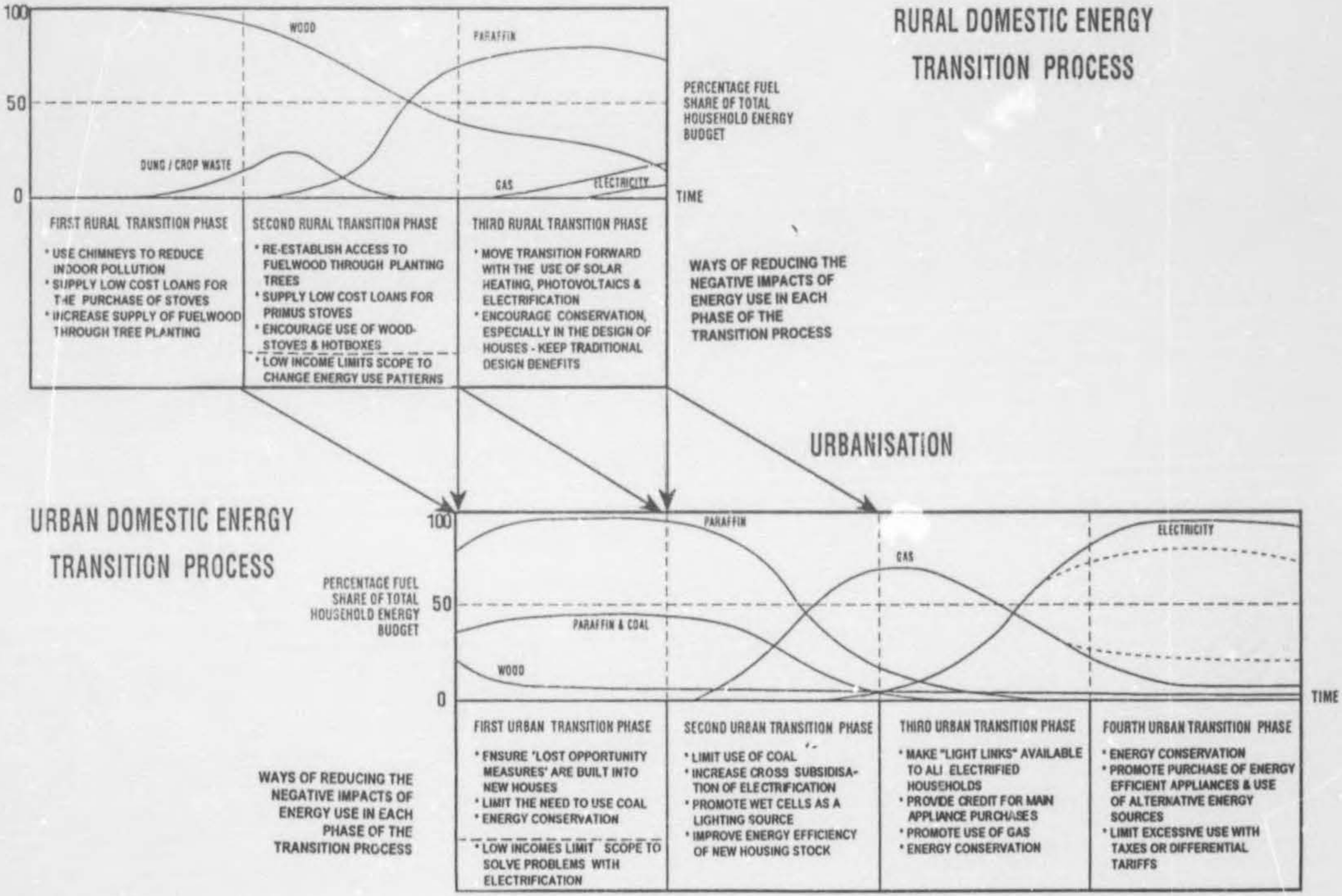


Figure 7.7: Ways of reducing the negative impacts of energy use in each phase of the domestic energy transition process



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